

STATISTICAL STUDIES OF FLOWER NUMBER PER HEAD IN CICHORIUM INTYBUS: KINDS OF VARIABILITY, HEREDITY, AND EFFECTS OF SELECTION

BY A. B. STOUT AND HELENE M. BOAS

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INTRODUCTION

Much study and speculation have been directed to the so-called fluctuating variations in the effort to determine their significance in development, in heredity, and in evolution. One of the principal reasons why such investigations have not been more conclusive undoubtedly rests in the difficulty of properly grading each of the individuals that comprise the species, the population, the generations, or the lines of descent to be analyzed.

This difficulty is frequently present in the more readily measurable or quantitative characters, especially when the estimate of the individual involves measurements of homologous organs among which there is also fluctuating variability. There are in such cases two grades of fluctuating variability: one is an individual variability (using this term as defined by de Vries, '01, p. 37, to refer to differences between individuals as such), the other is a partial variability (de Vries, '01, p. 37) which is a variability within the individual. The latter exists within the former and when present the estimate of the individual and of individual variability involves partial variability and is only adequate to the degree that the determination of partial variability is adequate.

It will also readily be recognized that partial variability may be complicated further by the development of homologous organs or parts of the organs at different times: the variations may involve organs which mature over a somewhat extended period either in different years or in a single season. A marked example of the latter is to be seen in perennials which produce a new crop of leaves, flowers, and fruit in consecutive years, giving inter-year variations which may involve the age of the individual. Furthermore, annuals, biennials, and perennials most frequently show a more or less extended period of development in a single season, during which homologous organs come into maturity with quite different positions on a plant and at quite different times.

All these aspects or factors of partial variability complicate the adequate determination of the expression of the capacities of an organism, and, it would seem, are factors that must be considered in an analysis of individual variability upon which any discussion of variation, heredity, or selection is based.

Furthermore, partial variability (as well as individual variability) may involve different kinds or grades of characters such as: (1) size, as of seeds, fruit, etc.; (2) chemical properties, as color, sugar-content, etc.; (3) number of homologous organs grouped together in a specialized structure such as the number of flowers in an inflorescence or the number of petals or sepals in a flower. Bateson has used the term "meristic" to apply to variation in number, as distinguished from substantive (such as color) variations which are more qualitative. The term "meristic" is, however, not applied solely to partial variability.

Further, partial variability may involve elements of differentiation which may not be suspected from random observations and collections of data, but which may constitute a source of error. The relation of fluctuating variability to differentiation is by no means clear, as the discussions of Pearson ('01 and '02a) and Bateson ('03) indicate. Very generally, however, the element of differentiation has been entirely disregarded in statistical studies of characters exhibiting wide partial variability.

The development of varying numbers of flowers in the different heads produced on a plant of a species of Compositae illustrates a type of partial meristic variation in the total number of flowers

per head. If there be a noted differentiation among the flowers in a head, the number of both ray- or disk-flowers may vary. The compact inflorescence terminating a branch is itself considered as a unit structure in the study of partial variability upon which the value of the individual is to be based. The study of flower number in the Compositae, particularly the variation in the number of ray-flowers, has received much attention. The biometrical treatment inaugurated by Quetelet and Galton has been utilized in the descriptions and analyses of the performance of a species as a whole and of various populations and lines within a species. These studies have not always recognized the extent and kinds of individual and partial variability that may exist, or the degree to which differentiation may be recognized as operative in what appear as chance variations. The reasons for this will be obvious from the following considerations of the points of view and aims which influenced and guided different investigators in their studies.

REVIEW OF LITERATURE PERTAINING TO NUMBER OF FLOWERS PER HEAD IN THE COMPOSITAE

I. LUDWIG'S EVIDENCE THAT FLOWER NUMBER IS A SPECIFIC CHARACTER

Ludwig was one of the first to investigate intensively botanical subjects by biometric methods and his studies were especially directed to problems relating to number of flowers per head in various Compositae. He also investigated species of Umbelliferae as to the number of rays per umbel. His interest at first centered on the analysis in Galtonian terms of flower number *for species as such*. In the Compositae he studied those species which have both ray- and disk-flowers, but confined his observations almost exclusively to ray-flowers.

Ludwig did not realize the importance of the behavior of the individual plant, hence his method involved counts of heads collected indiscriminately. From such data curves were constructed to determine the behavior of the particular species, and especially to determine the highest mode or the maximum frequency of number per head. In the collection of data therefore, for the most part, no special recognition was given to individual variability and, of course, partial variability was ignored.

Ludwig ('95) published a summary of all his studies, which involve twenty-six genera and over sixty species of Compositae. The maxima determined for the number of ray-flowers per head are given for the different species. Often the counts were made from only a few flower heads so that the maximum is frequently not to be considered as established, as Ludwig himself fully recognized.

The largest number of counts made of any composite was of *Chrysanthemum Leucanthemum*. Data for 17,000 heads were collected in Europe at different places and at different times of the year over a period of several years. Ludwig concludes that 21 ray-flowers per head is the number characteristic of this species. In no instance does he give data showing that a race with a different maximum was found growing in isolation, but he considered that such races were indicated by secondary maxima obtained from data of mixed populations.

Data for ray-flower number of approximately 12,000 heads of *Bellis perennis* (Ludwig, '98) were presented to show that maxima may occur on the "Nebenzahlen" of the Fibonacci series, i. e., 39, 42, 55, 63, which were considered as "duplica" or "triplica" of various numbers of the main series. The only maxima that can be considered as at all established for *Bellis perennis* are 34 (one of the main series) and 42 (twice 21). Study was also made of total flower-number per head in *B. perennis*: 860 heads were counted and for these the range was from 63 to 233, a very large range of variability.

For *Chrysanthemum inodorum* (Ludwig, '95), data for 1,000 heads reveal a range in ray-flower number from 10 to 32 and a pronounced maximum at 21.

The data for *Chrysanthemum segetum* (Ludwig, '04) are of special interest as this is the species in which de Vries later made selection experiments. Ludwig reports 750 counts made in one locality and 250 made in another. Of the 750 from the one locality, 150 were made on July 29 and 600 on August 30. The 250 counts in the other locality were made on August 16. This is the only instance where Ludwig reports the dates of collections. However, the two series show no significant differences either in maxima or in range of variability; for the 750 counts the maximum

is at 13 and the range from 11 to 23; for the 250 counts the maximum is 13 and the range from 10 to 23. Ludwig thus failed to find any evidence that here differences in flower number may appear according to age of a plant or to different stages in the period of bloom, such as will be reported in this paper for *Cichorium*.

For *Anthemis arvensis* Ludwig ('95) reports that for 1,802 flower heads the number of ray-flowers ranged from 2 to 21 with a maximum at 8 and some indications of a secondary one at 12-13.

In only two cases did Ludwig ('87) make a study of individual plants. In *Achillea Ptarmica* the modes for number of ray-flowers were determined for each of 79 plants; 30 plants gave a mode at 8; for 17 the mode was at 13; and for the other 32 the modes were about evenly distributed at numbers ranging from 9 to 12 inclusive. The total number of flower heads counted was 1,048 and the number of ray-flowers ranged from 6 to 15, with a maximum at 8. For *Senecio Jacobaea* the distribution of ray-flower number for 5 individual plants was studied. The range here was small, being from 12 to 14 and the total number of heads counted was 109.

In only a few cases does Ludwig consider the number of all the flowers produced per head. Such a study for *Bellis perennis* has been noted above. For *Senecio nemorensis* he presents ('96) data for 500 heads, which show that the total flower number per head ranged from 15 to 26 with maxima at 18 and 21, and the maximum for the ray-flowers in 357 heads of these was 5, with a very small variability. In these studies, however, the behavior of individual plants was not considered. Studies of total flower number were made in *Senecio Fuchsii* ('96), *Centaurea Cyanus* ('96), *C. Jacea* ('96), and *Solidago Virgaurea* ('96), but the number of observations is too small for the determination of the specific characteristics, which was the object of his interest and studies.

II. THEORIES REGARDING THE EVOLUTION AND DEVELOPMENT OF FLOWER NUMBER PER HEAD

A most important conclusion which Ludwig reaches from his studies is that the maxima for the number of ray-flowers and the total number of flowers in the Compositae and the number of rays

per umbel in the Umbelliferae all follow the series of Fibonacci (1, 2, 3, 5, 8, 13, 21, etc.), the maxima differing for different species, or for different races of the same species. He sought to relate deviations from this series to the "Nebenzahlen" of the series, i. e., 39, 42, 55, 63, which may be considered as "duplica" or "triplica" of certain of the main series ('97a).

However, in discussing various views regarding phyllotaxy, Ludwig ('97b) suggests the development of other series than the Fibonacci ($1/2$, $1/3$, $2/5$, $3/8$, $5/13$, etc.). The *Trientalis*, for example, differs in giving the series $1/3$, $1/4$, $2/7$, $3/11$, $5/18$, etc.

Evolution in regard to flower number was thus held by Ludwig to be discontinuous, so that the various species in a phylogeny represent a series of discontinuous variations with values for flower number which depend on that of the original species.

The number of flowers realized in ontogeny was considered to be determined first by the divisions initiated in the mother organ ("Mutterorgan"), and, second, by the processes that determine phyllotaxy. The suggestion is made that the development of a flower head or of the number of rays involves one complete turn of the spiral. Ludwig, however, does not attempt to correlate flower number with the phyllotaxy of the species, and in the Compositae he does not find maxima that correspond to any other than the Fibonacci series or duplica or triplica of its various numbers.

Ludwig's later ('95) theoretical conceptions of the morphogenetic processes involved in the development of the different numbers of ray-flowers are based chiefly on the observations of Otto Müller ('83) on *Melosira*. In this diatom the individual cells remain attached, forming filaments. The development of the filamentous colony Müller claims to be as follows. Cell division, as always in diatoms, occurs in such a way that of the two daughter cells one is larger. The larger then divides while the smaller one rests. Then the latter divides simultaneously with the larger of the newer pair. Thus one cell divides, giving two; of these, one divides making three cells in the filament; two of these next divide, making five in all; three of these divide next, making eight in all, etc. It is thus claimed that there are rhythmic and periodic divisions in which all the older cells divide together with one half of the newer cells. As a result, the number of cells

in the filament increases according to the Fibonacci series, 1, 3, 5, 8, 13, 21, etc.

On the basis of these observations, Ludwig explained the occurrence of maxima for ray-flowers, which he considered to correspond to the series of Fibonacci, on the hypothesis that in the development of such organs as ray-flowers, one part is like the mother organ and another is like the offspring. The mother organ forms new parts in rhythmic succession, the offspring goes through a ripening period and then divides. In Ludwig's own words, "Das Mutterorgan grenzt fortgesetzt in rhythmischer Wiederholung neue Teile ab, der Spross teil dagegen immer erst in der folgenden Teilungsperiode, nachdem derselbe herangewachsen ist." (Quotation from Vogler, '12.) The term "mother organ" is used vaguely. Whether it is considered as a fertilized egg or as the apical growing-point in the main stem or in lateral stems is not stated. What significance partial variability may have is not discussed.

Ludwig later ('04) brings this conception forward in support of the mutation theory which had then recently been announced by de Vries. The emphasis was laid on the discontinuous increase in the number of cells and organs involved in such rhythmic divisions. In the Compositae, for example, the various species are considered to represent different steps in a series, the number of cell divisions are assumed to stop at certain points and become hereditary. However, in referring to de Vries's studies, later to be discussed here, Ludwig ('04) considers that it is possible to change by cultivation the stage or step which has been reached by a species.

As a theory of morphogenesis, the conception is interesting and suggestive. It is not indicated, however, how a series of rhythmic linear divisions, such as may occur discontinuously in filamentous forms, is to be applied to complex growing-points involving various histogens where various groups of cells are concerned in the production of an organ, as in the case of the formation of a composite flower head, and especially in the application to the number of differentiated ray-flowers constituting only a part of the head. Furthermore, the correlation of characteristic numbers for a species with the phyllotaxy is not attempted.

Weisse ('97) attempts to refer the position and number of flowers in the head to the mechanism of phyllotaxy, as conceived by Schwendener ('78, '85). According to this view, the arrangement of lateral organs, as leaves, is determined by the pressure they exert upon one another when in the embryonic condition. The arrangement and relative position of matured organs is hence not definitely related to divisions taking place in the growing point, but is dependent on the mutual pressures between organs already present and above which the new ones are being formed. Weisse's observations were made on 141 main flower heads of *Helianthus annuus*. The most definite facts revealed are that as the ray-flower number increases more disk-flowers are laid down before two are in contact and that there is much variation in the phyllotaxy immediately below the flower head. There seems to be an increase in ray-flower number with higher values of phyllotaxy, but the great range of variability (13 to 82) in ray-flower number and the small number of cases do not permit of a very definite conclusion.

III. SPECIAL CRITICISMS OF FACTS AND THEORIES

Vogler ('12) discusses especially the theories held by Ludwig. He points out that Ludwig ('87) at first related development of flowers in a head to processes concerned with the mechanism of leaf position, but that as early as 1888 he (Ludwig, '88) refers the phenomenon to certain types of rhythmic cell division which were later more fully formulated by him (Ludwig, '95 and '98). Vogler points out that the two processes (1) the mechanism of phyllotaxy and (2) periodic divisions are not necessarily exclusive, and that leaf arrangement may be due to the same kind of periodic cell-divisions as are involved in the production of flowers in a head.

Furthermore, Vogler ('12) appears to contend that the development of certain numbers as maxima rather than others does not involve the reproduction of Anlagen according to the scheme of Fibonacci, but results from the continuation of the phyllotaxy in the arrangement of the number of parts of the flower head. "Diese Bevorzugung bestimmter Zahlen ist nicht die Folge einer Vermehrung der Anlagen nach dem Schema des Fibonacci, sondern ergibt sich aus dem gesetzmässigen Anschluss an die Spiral-

stellung der Blätter." He is evidently led to this view chiefly by his observation that partial variability is strongly in evidence. Also in summarizing the statistical work done in the Compositae, he ('11) finds that only about 85 per cent. of the species exhibit maxima that fall on main and duplica numbers of the Fibonacci series.

Vogler's ('08, '09, '10, '11) original studies on Umbelliferae and Compositae bear directly on the question of maxima and their occurrence according to the law of Fibonacci. His study of the umbellifer *Astrantia major* L. ('08) is of special interest, for here he finds the maxima for the number of bracts, perfect flowers, and male flowers to be lower for lateral umbels than for those on the main stem. In all cases the variability was less for the parts of the lateral umbels than for the main umbels. His conclusion is that the maxima for the parts of the umbels of the main stem follow in general the series of Fibonacci, while those of the lateral stems follow another and quite different series, the Trientalis. Vogler also reports data on the number of ray-flowers in 31,000 heads of *Senecio alpinus* ('09, '10) collected at different localities and at different times of the year. For these the number ranges from 10 to 28 with a maximum at 19, which, as he points out, is not one of the primary or secondary numbers of the Fibonacci series.

In the case of two plants of *Boltonia latisquama*, Vogler ('09, '10) studied the production of flowers in successive years. For three successive years 500 flower heads were counted on each. Although the weather conditions were different in the three years each plant was quite constant in respect to ray-flower number during the three years of observation.

Furthermore, Vogler ('10) undertook in *Arnica montana* and *Eupatorium album* to determine various facts of partial variability, especially the relation of position of heads to variation in the number of ray-flowers. In counts made on ray-flowers of *Arnica montana* in 1909 and 1910, he separated data for terminals and laterals. In both years the terminals gave a higher average ray-flower number than the laterals. In 1909, 266 terminals averaged 14.7, while 153 laterals averaged only 11.6. In 1910 (counts were made in a different locality from that of 1909), 314 terminals

averaged 15.1, 149 laterals only 11.1. In both years the maximum for terminals was 13, a number of the Fibonacci series, that for laterals 11, a number of the Trientalis series. More intensive studies were made of partial variability in one plant of *Eupatorium album*. This species has only tubular flowers and the counts were hence made of the total flower number. The plant studied had six branches. On each branch Vogler counted the terminal heads, and then the laterals in succession downward. The most noticeable points brought out by his data are that the flower number is different for the various main branches and that on the same branch the number is different for terminals and laterals, especially for branches near the top of the plant.

A survey of Vogler's work shows that the maxima do not always accord with the series of Fibonacci; they may fall on other numbers such as certain of the Trientalis series. He has also observed and emphasized the significance of partial variability, which he views as evidence against the conception that rhythmic divisions give harmony between mother and daughter organs as to position and number.

IV. EVIDENCE OF INTRASEASONAL VARIABILITY

Some interesting observations regarding intraseasonal variability in number of flowers per head are reported by MacLeod ('99). He found that the ray- and disk-flowers of *Centaurea Cyanus*, *C. alba*, and *C. atropurpurea*, whether from terminal or from lateral heads, are more numerous per head early in the season than later. However, as he studied heads indiscriminately, there are no data on the individual behavior of plants. He grew some of his plants on poor and some on rich soil and found that those on poor soil had a lower flower number per head than those on rich. He rightly points out that experimental breeding work of this kind is necessary in order to determine whether differences are due to heredity or merely to food supply and season.

Tower ('02) reported differences in flower number for heads of *Chrysanthemum Leucanthemum* collected in the same location, but at different dates (July 5 and 30) of the same season. When grouped, such data gave a bimodal curve involving what he calls "secular modes."

Further analysis of intraseasonal variation has been made by Shull. He ('02) made successive collections of heads of *Aster prenanthoides* and counted the bracts and the ray- and disk-flowers per head. The heads were taken from plants growing wild on a "single small plot" and were evidently collected indiscriminately. On the first date of collection records were made from 117 heads, on the second from 143, on the third from 139, and on the last from 116. The average number for all the organs counted decreased in number as the season advanced. Later ('04) he gives data for twelve successive collections, made from September 12 to October 9 in 1903; the curves show low values at first, then a sudden rise, which is followed by a gradual decrease and a sudden rise at the end of the season. The rise at the end of the season can hardly be considered to be significant, since it was determined from only four heads. Shull attributes seasonal variability here observed chiefly to individual variability rather than to partial variability. He suggests that the low flower number seen early in the season is due to weak or starved individuals which bloom first and which have a lower flower number than is normal for the species, but his data being indiscriminate do not determine the facts regarding this point. Further, his view raises the question of the adequacy of judging vigor by the number of flowers per head. The data later presented in this paper for chicory will show that partial variability may have been involved as the principal cause of the seasonal decrease observed by Shull.

V. OBSERVATIONS AND EXPERIMENTS ON THE INFLUENCE OF ENVIRONMENT

With the recognition that the number of parts in an inflorescence is often subject to considerable variability, certain experimental studies were made regarding the influence of nutrition. Some of these have a very direct bearing on the factors involved in both individual and partial variability.

Weisse ('97) sowed seeds of two heads of *Helianthus annuus*; half of the seeds of each was sown in pots containing sand, and half was sown in ordinary garden soil. The ray-flowers in the terminal heads were counted. The 155 heads from plants grown in sand had an average ray-flower number of 21 and a standard deviation

of ± 6.6 . The 221 heads from plants grown in the garden had an average ray-flower number of 37 and a standard deviation of ± 9.2 . These differences observed were quite evidently due to the effect of nutrition. A point that is of interest and that Weisse does not call attention to is the smaller variability of the starved plants. Weisse states further that certain plants that were heavily manured had as many as 82 ray-flowers in a head and a maximum at 55; while heads with less than 30 ray-flowers usually were found on plants which were checked and retarded in growth by the crowding of neighboring plants. Weisse combines the data obtained from the two cultures, the one on sand and the other on garden soil, and points out that the resulting bimodal curve, having a maximum at 21 and one at 34, is a result of different nutritional conditions under which the population was grown. He believes such conditions might readily occur in nature and that bimodal curves that have been ascribed to the mixture of two races are often due to differences in nutrition occurring in nature.

MacLeod ('99) published some observations on *Centaurea atropurpurea* which show the effect of nutrition on the number of ray- and disk-flowers. Here again there is a lower flower number under conditions of poor nutrition, but the number of disk-flowers seems to be more affected than that of ray-flowers. MacLeod gives only the averages for each culture, so that the variabilities of the cultures cannot be determined.

De Vries ('01) repeatedly states that favorable environmental conditions, such as optimum water-supply and manuring, tend to increase the size of organs (fruits of *Oenothera*) and the number of parts, as the number of rays in the umbels of Umbelliferae or the ray-flowers in the heads of Compositae.

Danforth ('08) comparing ray-flowers of the daisy growing in a well-drained situation with those in a drier situation, reports a lower mean and less variability for the latter. Koriba ('08) made successive collections of heads of *Arnica unalaschensis* (also some other Composites) from two different localities, one from a valley and the other from the slope of a mountain. Those on the slopes were growing under the least favorable conditions and gave uniformly lower values.

Detailed studies by Burkill ('95) show that the number of stamens in flowers of *Stellaria media* increases during the first two weeks of bloom, then there is a gradual decrease to the end of the flowering season. Reinöhl ('03) working with the same plant showed further that the plants grown in poor soil produced flowers with a lower number of stamens. Tammes's ('05) studies of the effect of good and poor soil conditions on various characters show lower values for many of the characters of poorly nourished plants. Love's researches ('11) are among the most recent that deal with the effect of nutrition on the mean of such characters as height, number of peas per pod, weight of seeds, etc., in such plants as peas, buckwheat, and corn. His results agree with those mentioned above, that is, he finds an increase in the mean and in the variability, as a result of better nutrition.

VI. STUDIES OF INTERANNUAL VARIABILITY

In the consideration of interannual variability, at least two distinct aspects are to be recognized. First, the season of growth may differ in a way that affects the plant, and, second, in the case of perennial plants the age of the plant may be a factor in variability just as the period of development may influence the partial variability seen in a single year of growth. These two factors have rarely been distinguished and little attention has been directed to the factor of age, for flower number studies have been chiefly indiscriminate for the population.

Haacke ('96), it seems, is the only investigator who has attributed variation in the number of ray-flowers of composites to the age of the plant. He suggests that older plants probably have more ray-flowers per head. His observations on *Chrysanthemum Leucanthemum* and *Anthemis arvensis* were not conclusive, however, for he did not know the age of the plants studied.

Yule ('02) gives the results of counts made in three successive years of the number of sepals in a population of *Anemone nemorosa* from one habitat. He gets differences in the means for different years and calls attention to the importance of observing "local races" for several years before one can determine the characteristics of a species. Shull ('04) made a similar study for a population of *Aster prenanthoides* and obtained higher mean values for

bracts, rays, and disk-flowers for 1900 than for 1903. He attributes this to more favorable climatic conditions in 1900 and points out the importance of taking differences due to climate into account in determining "place constants."

Clark ('10), working with timothy, calculated coefficients of correlation for the same character in different years. Following Tower he calls these coefficients of "place variation." He correlates height in 1905 with that in 1906, height in 1906 with that in 1907, and height in 1905 with that in 1907. He does the same with weight. He finds considerable correlation, which means that in spite of varying conditions, such as climate, plants high in values one year will be high the next.

Harris ('15) has recently called attention to the different values of interannual correlation for different characters. This study gives a comparison of data of the same sort for successive years by means of correlation tables, as Clark ('10) has done in the paper just mentioned. The degree of relation is then expressed by the coefficient of correlation. This method has been used especially in studies on growth in man (Boas and Wissler '05), and Harris refers to work of Pearl and Surface on egg-production and Gavin on milk records, where interannual coefficients of correlation were used. Harris published data for interannual correlations for fruits of *Staphylea trifolia* and *Hibiscus syriacus* in which he gets various degrees of correlation according to the parts of the fruit studied; for example, for 23 fruits of *Hibiscus* he finds the correlation for 1907 and 1908 to be for sepals and sepals $+0.46$, for bracts and bracts $+0.84$, for ovules and ovules $+0.94$, for seeds and seeds $+0.63$, etc. While these studies indicate that the degree of correlation may be different for different characters, they are not especially concerned with the analysis of changes in values for a single character due to such a factor as age.

VII. EVIDENCE THAT POSITION IS A FACTOR IN PARTIAL VARIABILITY

With the recognition of the existence of partial variability there developed further refinement of study which aimed to determine the relation of position on a plant to difference in number of parts. Burkill ('95) gives indiscriminate data for 102 flowers

of *Caltha palustris* which indicate that the number of stamens and carpels is larger in terminal flowers than in laterals.

Haacke ('96) made a detailed study of ray-flower number of *Tanacetum corymbosum*, taking into account the position of the heads on the plant. He studied 81 plants and presents data for each plant separately. The largest number of heads for a single plant recorded is 14. There is one flower head at the end of the main stem, which he calls primary. There are, on the average, four or five unbranched branches each bearing a terminal head. These he calls secondary heads. There usually follow several branched branches, which bear secondary and several tertiary flower heads. The lower branches of the plant are longest, thickest, most branched and the secondary heads on these branches are about the same distance from the ground as the primary head. In other words, the lower branches have the greatest similarity to the plant as a whole. He found that the primary head had on the average the highest number of ray-flowers, the secondary head of the first branch the lowest. There was then an increase in the number of ray-flowers of successive secondary heads. From the tenth branch downwards the number of ray-flowers of the secondary heads was the same as that of the primary head. There was a correlation between ray-flower number in the primary head and of the secondary and tertiary heads; those plants having high or low numbers in the primary had correspondingly high or low numbers in the others.

MacLeod ('99) made a similar study of the flower heads of *Centaurea atropurpurea*. He does not, however, keep the data for individual plants apart and his results are not as clear as those of Haacke. He first counted the terminal heads of the main axes, 424 in all. The average total number of flowers (disk and ray) in these was 47.7. He then examined the heads on the branches. Of these the first group consisted of 524 heads in bloom between July 10 and 12. These had an average flower number of 39.2, considerably lower than the average for terminal heads. He calls this a "bud-generation" (knopgeneration). After seven days he cut off all the open flower heads, and his second "bud-generation" consisted of 656 heads blooming from July 21-25, and with an average flower number of 34.4 flowers per

head. He continued in this way to the end of the flowering season and got a decrease in flower number in successive "bud-generations." The only fact revealed that clearly bears on the question of flower number in relation to position is that there appears to be a higher flower number for terminal heads than for those borne on side-branches.

Schüepp ('13) has made detailed statistical studies on *Aconitum Napellus*. One of his chapters is devoted to variations within the individual (partial variability) and his data show that to a certain extent quantitative characters are functions of the position of the organ on the plant. This is very apparent for a character like leaves, which in the vegetative parts are petioled, large, and have 40-50 points, while in the reproductive regions they are sessile, small, and one-pointed. He also gives the number of perianth parts, nectaries, stamens, and carpels for three regions, base, middle, and top of plant, and in all finds a slight decrease in the number of parts from the base upward.

Klebs ('06) showed that there were slight differences between lateral and terminal inflorescences in *Sempervivum*. Vogler ('12), whose work has been discussed earlier, presents data to show differences according to position between number of flowers in the inflorescences of Umbelliferae and Compositae.

Such differences as have been noted have a bearing on the much larger question of the periodicity shown in the development of an individual plant. Braun, Sachs, van Tieghem, J. W. von Mohl, and de Vries have contributed much to this question. Tammes ('03) reviews the literature on this subject and gives to von Mohl the credit of establishing the fact that there is a periodicity in cell division, so that the longer internodes have more as well as longer cells than the shorter. Tammes ('03) investigated a large number of plants and showed that there is a periodicity in development for length and breadth of leaves, length of petioles, and number of main veins.

These studies show that partial variability in respect to the number of parts in a complex structure such as a flower or a flower head is to some degree related to position on a plant involving time of development, and therefore introduces an element of differentiation. This places an emphasis on processes of devel-

opment which give a periodicity or a sort of polarity. The processes assigned by such conceptions as that of Ludwig to rhythmic cell divisions which give specific differences for species as such may themselves undergo change, continuous or discontinuous, in the development of successive parts of a single individual.

VIII. SPECIAL VIEWS REGARDING HEREDITY, DIFFERENTIATION, AND SYMMETRY, HELD BY PEARSON AND BY BATESON

While Pearson's studies of numerical qualities in plants do not pertain to number of flowers in any of the composites, they are of special interest in the recognition that differentiation is a factor in partial variability seen among organs of the same kind. They also illustrate very well the difficulties of adequately determining the heredity of such a character as the number of stigmatic bands or seed chambers in fruits of poppies, of *Nigella hispanica*, and of *Malva rotundifolia*.

Pearson's earlier report ('01) bears on the statistical and mathematical demonstration that "undifferentiated like organs" or "homotypes" on an individual are alike only to a certain degree. The degree of likeness between homotypes as measured by his methods of determining homotypic correlation, has on the average a mean value of 0.4-0.5, which is, he considers, quite identical with the general value for fraternal correlation. Thus he concludes that heredity is a phase of homotyposis and that the sources of variability are to be sought in the individual. The distinction between differentiated and undifferentiated like organs is not, Pearson recognizes, always easy to make. In general, the former class involves function, position on the individual, season of production, etc., and is statistically discoverable by testing the frequency distribution for heterogeneity. In contrast to this, Pearson distinguishes variability of "undifferentiated like organs" as due to "that combination of small causes, inherent and environmental, which leads to what is familiar in both theory and observation as a homogeneous chance distribution" (p. 287).

We may note that when such differentiations as exist in the poppy and in *Nigella* are thus treated as pure chance variations the statistical treatment may give a high or low value for homotyposis. The existence of differentiation is not necessarily re-

vealed by such treatment of data. It is to be determined only by observation and by a refinement of methods of collecting data.

Pearson's first studies ('02b) pertaining to the heredity of the number of stigmatic bands in capsules of the Shirley poppy are of special interest, for here data were collected from all capsules. These data were statistically treated by three methods:

1. The correlation of all offspring capsules with parental mean capsule, the various progenies grown in each locality being thrown together in a single correlation table.

2. The comparison of the average variability of an array of offspring of a single parent plant with the variability of the offspring population. Here the means for individual offspring were determined.

3. A mathematical consideration of homotypic relationship in correcting the parental correlation determined by the first method.

According to the first method the parental correlations for the different crops, as a whole, range from 0.3230 to 0.1220. The highest correlation of 0.3230 was obtained in the "most starveling crop" which had few capsules per plant and the low correlation of 0.1220 was obtained in the crop that was most luxuriant in growth. Here is definite evidence that the greater vigor of growth affects individual variability by increasing very much the partial variability. On this account the method of collecting data and the statistical treatment give lower parental correlation when there is increased vigor.

In one crop of 907 plants the means were determined separately for each plant and these were correlated with the mean of the parents. The value was 0.1561 as compared with 0.1864 obtained for the same crop by the first method. Here Pearson attributes the low parental correlation to "differentiation" and reports that the flowers that come out "early in the season have fewer bands than those which come later" and that "the number of capsules to the individual plant, and the dates at which it produces them, tend to obscure the influence of pure heredity, and make the stigmata, however easy to count and deal with a by no means ideal character to study heredity upon" (p. 72).

The low values obtained for parental correlation were, however,

not considered as correct because homotyposis was involved. The true parental correlation, according to Pearson's conception, was higher. By accounting for homotyposis the value was raised from the average of 0.20 to a value lying between 0.35 and 0.40.

It would seem that much of the difficulty here experienced in attempts to make exact determination of values, even for populations such as Pearson studied, lies in treatment of all the variations as "chance." Although Pearson definitely recognizes that lateral flowers are differentiated from terminals, there is no attempt to determine values for such partial variability.

In further studying heredity of number per capsule in the poppy, Pearson ('06) sought to avoid the difficulties previously encountered in estimating the individual when multiple observations involving partial variability were made. He attempted to do this by "confining the attention to the first or principal flower." In 1903 and 1904, crops were grown from seed of random samples in 15 different localities and treated as populations. Differences in mean and in variability were found which were attributed to effects of environment as affecting individual variability and which were so great as to be "not directly comparable." It was possible to determine parental correlations for these results in only one population; a crop grown in 1904 from parents of a 1903 crop, the two crops, however, were grown at different localities. The raw correlation was only 0.1717.

Pearson therefore concludes that the determination of heredity even for such an easily measured quality as the number of stigmatic bands in pods of the poppy is exceedingly complex and difficult, and he now questions "whether the apical flower is as true a measure of individuality as the totality of flowers on the plant" ('06, p. 400).

Pearson is here concerned with population studies and in intensity of parental correlation for rather mixed populations. His treatment and results suggest and in fact reveal many sources of variability. His rather uncertain results raise very definitely the question of how to value adequately a numerical character which exhibits elements of both chance and differential variability for both partial and individual variations.

Bateson ('01, '03) questions the validity of Pearson's distinc-

tion between "chance variation" and "differentiation" in the treatment of homotyposis and heredity. He insists that "meristic" variations are discontinuous and doubts that "there is a true material distinction between variation and differentiation as applied to parts of the same organism." Bateson further objects to a comparison of "undifferentiated like organs" with the correlation between brothers which may be differentiated as individuals. He evidently views the partial meristic differences of organs of the same kind actually in evidence in such plants as *Nigella*, *Cichorium*, etc., as a differentiation of the same rank as differentiation between individuals as such ('03, p. 23). Bateson emphasizes the aspects of symmetry, advocates an extreme view that tissues and organs arise somatically by "differentiant or segregating divisions" in much the same sense as Weismann postulated, and he thus questions the adequacy of the term "chance variations." He is perhaps strongly influenced by his earlier studies of meristic variations in animals in which differentiation and symmetry are in marked evidence, and by the views of segregation of hereditary units representing characters which may give differentiation between individuals of the same hybrid origin.

IX. EVIDENCE OF HEREDITARY VARIATIONS

There appears to be no report of researches directed to the study of selection and heredity involving only total flower number per head in any of the Compositae. There are, of course, many species in cultivation from which double-flowered varieties have been developed, the history of which does not involve statistical studies of total flower number. Moreover, the development of so-called double-flowered composites does not necessarily involve increase or decrease of total flowers per head, but a change of such flowers as tubular disk-flowers into strap-shaped or ligulate flowers more like the ray-flowers.

The studies of de Vries ('01) on *Chrysanthemum segetum* are of interest in their bearing on selection, heredity, and evolution of flower number. He first isolated a race having a maximum of 13 ray-flowers in the terminal heads. Then he isolated a race with 21 ray-flowers in the terminal head. In this case, however, he considered it necessary to judge his plants not only by the ray-

flower number of the terminal heads, but also by the ray-flower number of the later heads, for he found that some plants having 21 ray-flowers in the main head gave for all flower heads curves with maxima lower than 21, often at 13 or 14. These plants were discarded as not belonging to the desired race and only those giving "partial curves" (the curves obtained from the flower heads on a plant) with maxima at 21 were retained. No attempts were made to isolate races with numbers intermediate between 13 and 21, and no further studies were made of the very irregular cases of partial variability which were in evidence.

After isolating the two races, de Vries observed variation in the race with 21 ray-flowers in terminal heads in respect to increase of ray-flowers. In a crop of 1,500 plants one was found with each of four lateral heads having 22 ray-flowers, a higher number by one than was previously seen in any of the terminal heads. Open-fertilized seed of this plant gave a progeny in 1897 of 414 plants; the number of ray-flowers in terminal heads ranged from 14 to 34. From seed of the plant having 34 ray-flowers in 1898, 241 plants were grown; for these the range was 19 to 48; the modes were at 26 and 34. The average of the population was 38. The next year 194 plants, offspring of the plant with 48 ray-flowers, produced terminals with ray-flowers ranging from 19 to 67; the modes were scarcely pronounced at 32, 37, and 45, and the average number of rays was 41.5. In this crop, it is stated, ligulate flowers appeared among the disk-flowers in one head of 62 ray-flowers. The seed of this plant gave a progeny in 1900, 31 plants in all, ranging in ligulate flowers of terminal heads from 33 to 101; there were no pronounced modes either primary or secondary; the average number was 53.2. One plant had some heads with only ligulate flowers.

Evidently for the first few years there was an increase in the size of the heads and the accompanying number of ray-flowers. Then there came also a change of disk-flowers to ray-flowers. Throughout there had been great irregularity in heredity revealed in range of numbers observed in individual variability both for data of terminals alone or for terminals and laterals. Such variation de Vries assigns to mutation and attempts to show that the increase in number follows the Fibonacci series. There can be

no doubt that spontaneous variations here occurred, giving increased variability, and that selection of the extremes was effective in giving a new race.

X. PREVIOUS STUDY OF FLOWER NUMBER IN CICHORIUM INTYBUS

It appears that the only statistical study of flower number in a species in which the flowers are all ligulate is that of de Helguero ('06).

His data were obtained from *Cichorium Intybus*. He counted the flowers in 1,000 heads produced by 624 individuals; the counts were made on five different dates during August when the plants were approaching the end of the blooming period. "Le piante furono raccolte in 5 diverse volte durante il mese di Agosto e perciò nel periodo decrescente della fioritura." Of the total 1,000 heads, 389 were from 389 plants which had only one head each in bloom at the time of collection: 300 heads were from 150 plants having two heads each in bloom when the counts were made: 311 heads were from 85 plants having 3 heads open on a single date. The data are treated almost solely to determine homotyposis. The table of correlation for the 150 pairs (two heads for each plant paired) gives a correlation of $+0.5915$. The correlation table for all pairing of two or more per plant gave a correlation of $+0.6130$. The results show that when a few heads (in most cases only two) are taken from a plant on a single date at the end of the blooming period the correlation is about $+0.6$. De Helguero did not extend his observations sufficiently to determine adequate values for partial and individual variabilities.

XI. SUMMARY

Statistical studies of such a numerical character as number of parts in an inflorescence were initiated about twenty five years ago by the very general collection of data from mixed populations. The method was to study species *en masse*. The chief aim was to discover specific qualities. Broad generalizations were made (1) that flower number is specific for species, (2) that the numbers characteristic of species fall in a series such as that of Fibonacci, and (3) that evolution giving such differences has been discon-

tinuous. The further important conclusion was reached that such discontinuous specific differentiation arises through processes operating in the development of the individual and these processes were assumed to involve rhythmic cell divisions. It was also suggested that there is a relation between flower number and phyllotaxy.

It was early recognized, however, that the maxima for species do not all fall in a well-defined series and hence attempts were made to show that in such cases other series were represented. From the first, it was evident that there was often a wide range of variation in flower number in a species, but the view was taken that the variations within a species or a race were solely due to chance, and that the facts could be accurately determined by Galtonian treatment of populations.

The more recent work has been very generally directed to the study of variation within a species. Processes operating within the population have received attention. Studies have become more particular and individual in scope. Various hitherto unrevealed sources of variability, intraseasonal, interseasonal, environmental, racial, individual, and partial were thus demonstrated.

To the present time, however, these studies have been largely dominated by the view that the variations are those of chance. The demonstration in a few cases that such variations, especially partial, are not purely due to chance, but may proceed in a discoverable manner, has revealed a source of possible error in much of the work done and emphasizes the desirability of combining extensive studies with a study of the organization of individuals as units.

It seems clear that intensive studies of individual and partial variabilities should serve as a basis for extensive study of species as such. Through such methods we may hope more adequately to determine the facts which serve as a basis of judgment regarding the processes operating in ontogeny, phylogeny, and evolution.

THE PROBLEMS IN CICHORIUM INTYBUS

The statistical studies here reported for *Cichorium Intybus* were begun with the aim of determining the facts as to partial and individual variability for such a character as the total number of

flowers produced per head. The nature of the partial variabilities was found to be such as to afford special opportunities for analyses of the intraseasonal and interannual variability and for a study of variation among heads according to position on a plant. The data were so collected that individual variabilities could also be determined. As the studies progressed interest extended to a study of heredity and the effects of selection in the different races which appeared and which were grown in pedigreed cultures.

MATERIAL AND METHODS

Cichorium Intybus is in many respects especially favorable for such study. The flowers are conspicuous and with the exception of an occasional tubular flower are all ligulate. The flowers of a head are readily distinguished and easily counted, as all the flowers of a head are fully expanded at the same time. A head opens but once and is usually expanded but a few hours during the forenoon, a behavior that somewhat limits the amount of data that can be collected in a day, but makes the collection of data from day to day more simple, as there is no danger of recounting the same heads. The flower number per head is not excessively high, which with the disposition of expanded flowers makes accurate counts a simple matter. A considerable number of flower heads open each day during a rather extended period of blooming. The numbers during the greater part of the season are sufficient to give at least ten heads per day for study. The abundant branching and the development of a large number of heads in various positions and at various times admits of rather full development of numerous parts of an individual and gives opportunity for the intensive study of various aspects of partial variability. The plants are, furthermore, hardy and easy to cultivate, so that numerous plants can be grown under as nearly the same conditions as is possible.

The cultures of *Cichorium Intybus* studied were, for the most part, the same plants whose behavior in respect to sterility (due to physiological incompatibility) has already been reported (Stout, '16, '17); they include mainly two somewhat distinct groups of plants, as follows:

In one group are F_1 , F_2 , F_3 , and F_4 generations derived by

crossing plants of wild white-flowered chicory and plants of the unimproved cultivated variety known as Barbe de Capucin. Some study was made of a few plants of the parent stock. The wild white-flowered parents (designated as *A* and *C*) were obtained in the autumn of 1911 from the campus of the University of Wisconsin and transplanted to the experimental plots at the New York Botanical Garden. In 1912 a crop of plants was grown from the open-fertilized seeds of these two plants. Plants of the variety Barbe de Capucin were grown in 1912 from seed obtained from J. M. Thorburn and Company (no. 4300, catalogue of 1911). These plants are designated the *E* series. All the plants of the first crop, of both wild and cultivated strains which were experimentally tested for self-fertility, were found to be self-sterile from physiological incompatibility. Crosses were made involving two plants of wild stock (*A* and *C*) and two plants of Barbe de Capucin (*E*₃ and *E*₂₂). Some of the *F*₁ progeny were self-fertile (Stout, 1916), and from these several self-fertilized lines of descent have now been grown in *F*₂, *F*₃, and *F*₄ generations and utilized in the statistical studies. The greater number of races and lines of descent reported later are descended from a single cross between a wild white-flowered plant (*A*) and one of the variety Barbe de Capucin (*E*₂₂).

Considerable data were also collected from plants of the inbred generations of a salad variety known as improved red-leaved Treviso, the seed of which was produced by the firm of Ernst Benary of Erfurt, Germany, and supplied by J. M. Thorburn and Company. One generation of 50 plants, *F*₁ hybrids between plants of red-leaved Treviso and the wild white-flowered plant *A* have also been studied. It should be stated that the seeds for all the cultures of chicory here reported have been sown in sterilized soil in small pans during the months of December and January, the young seedlings were transplanted to pots all properly labeled and grown in the greenhouse until the first of April, when they were transferred to cold frames. By the middle of May, when planted in the field, the plants as a rule have formed vigorous rosettes often more than a foot in diameter. With this treatment nearly all plants come into bloom in the first year of growth.

The plants of the Treviso strain, as well as such varieties as

improved large-leaved, improved white-leaved, and improved spotted, when treated this way come into heavy bloom and die as annuals. The plants of the Treviso strain have therefore been studied in only one year of bloom.

The preliminary studies of 1912 indicated that usually there is such a marked decrease in flower number per head as the season advances that data which are to be considered adequate should be taken during the entire flowering season. Hence, in the collection of data here reported, the method has been to begin on the first day of blooming and to continue throughout the season, obtaining counts of ten heads per plant, when that number was in bloom, on each of at least ten different dates per month at intervals of every third day, or as close to that schedule as conditions allowed. The flower heads counted were taken at random from various branches on the plant and from various parts of the different branches. The heads selected were usually removed, the flowers counted, and the number recorded on sheets specially ruled and tabulated for dates and numbers. In 1913 and 1914, many data were also taken on the character of each flower as to whether ligulate or tubular, as to number of teeth in the ligule and the depth of lobing. In 1915 and 1916 data were secured for flower number only. Special methods were used to obtain certain data; for all plants studied in 1915 data were taken every day during the first twenty days of blooming; and on five plants data were taken on all flower heads (excepting those that opened on Sundays or on days of heavy rainfall) with reference to their position on the various branches of the plant; this was done to determine more exactly the relation of position to time of blooming and to the intraseasonal change in number, both of which appear in the data as more generally collected. Data have been collected from a few individual plants during four successive years of growth, but the greater number of plants have been studied in the first of bloom.

Considering all plants of all stock, in 1913 data were collected from 63 plants, in 1914 from 110, in 1915 from 351, and in 1916 from 450. The total number of individual plants involved is 832. The number of heads counted approximates 5,500 in 1913, 20,000 in 1914, 113,000 in 1915 (including here data collected every day

for first 20 days of bloom), and 95,000 in 1916, making a grand total of about 233,500. The total number of individual flowers counted during the four years is about 4,200,000.

The collection of these data has taken much time and has involved the coöperation of several persons, as follows: In 1913, Dr. Joseph C. Gilman and Mr. Allen C. Fraser assisted the senior author of this paper in the collection of data. In 1914, Miss Friedolina C. Jud and Mr. Allen C. Fraser assisted the joint authors of this paper. In 1915, Miss Jud and Mr. R. C. Faulwetter assisted the writers. In 1916, Mr. M. V. Reed assisted during the months of July and August. In 1914, 1915, and 1916, Mr. Charles Holste, who was gardener in charge of the experimental plots, frequently assisted, especially when the work was pressing. Dr. Gilman in 1913, Mr. Fraser in 1914, Miss Jud and Mr. Faulwetter in 1915, and Mr. Reed in 1916 were recipients of scholarship grants from the Garden. In July, 1914, Miss Boas, joint author in the production of this paper, became a member of the Garden staff and took charge of the compilation and special methods of statistical treatment of the data. Miss Boas has made all the computations involved in this report and has assisted very materially in the search of literature. For the greater portion of the text, for critical discussions of literature, for discussion of results, and for opinions expressed in this paper the senior author is responsible.

Special care has been taken to insure uniform methods in the collection of data and the persons assisting collected from the same plants continuously at least during the period of their coöperation.

The somewhat laborious work of collecting such a large amount of data has been possible only through the hearty coöperation of the persons above mentioned. The authors wish here to express their appreciation of this coöperation and of the support of Dr. N. L. Britton, Director-in-Chief, in granting the scholarships as noted.

PRESENTATION OF DATA FOR FLOWER NUMBER IN CHICORY

I. GENERAL SURVEY OF THE KINDS OF VARIABILITY PRESENT

I. PARTIAL VARIABILITY

A. *Intraseasonal partial variability.*

The collection of random data on successive dates from individual plants reveals that, as a rule, there is a marked decrease in flower number per head as the period of flowering advances. Differences in number per head appear according to the stage of development of the plant as a whole.

The seasonal performance of a plant, as shown in such tables as 1 and 2, indicates that the number of flowers per head in heads as they appear from day to day is much higher during the early period of bloom than in the last days of bloom. This is indicated by both the daily range and the daily average. The change, however, is rather uniform and progressive as the season advances.

Partial variability, or variation among the apparently homologous heads produced by a single plant, is therefore seen in the range of the number per head; in TABLE 2 the range is from 12 to 23. But the daily data show that the range of values and the average value shifts from day to day. The variations from day to day are not therefore solely chance variations, since certain elements of differentiation appear.

The totals of all heads with the same number of flowers give what appears as a chance distribution. The chance collection of data for any period of time, as the first ten days, the second ten days, etc., would also give general summaries that would appear as chance variations; that such data do not adequately represent the individual seasonal performance is, however, very obvious. Random collections would hardly reveal the presence of intraseasonal variation; it is only the tabulation and computation of data for individual days from individual plants that clearly brings out such facts.

For the sake of completeness, there are given with the tables values whose significance will become clear later on. It is sufficient to point out here that a is the computed flower number for

TABLE I

SEASONAL DISTRIBUTION OF FLOWER NUMBER PER HEAD FOR PLANT E_3 OF BARBE DE CAPUCIN TWO YEARS OLD. DATA FOR 1913

Number of flowers per head	June			July														August								September		Total
	26	27	28	1	3	7	9	11	14	16	19	21	22	24	26	29	31	2	5	9	12	15	20	25	29	1	8	
14	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2	.....	.....	.....	.....	.....	.....	.....	2	4
15	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2	.....	1	1	.....	1	.....	2	2	2	3	.....	14
16	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	2	.....	.....	1	4	2	5	3	1	4	3	2	28
17	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	.....	2	2	.....	3	3	4	2	5	1	3	3	1	1	4	35
18	.....	.....	.....	.....	.....	.....	.....	3	1	.....	.....	1	.....	2	2	2	.....	1	1	4	4	3	1	3	.....	2	.....	30
19	.....	.....	2	3	2	5	4	4	2	4	6	5	.....	1	3	2	3	3	1	.....	1	1	.....	2	1	2	57	
20	.....	7	10	2	6	5	4	2	5	3	3	2	.....	4	2	1	4	.....	.....	.....	.....	.....	.....	.....	.....	.....	60	
21	6	6	9	9	1	.....	1	.....	.....	.....	2	.....	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	37	
22	3	.....	1	1	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	6	
23	.....	.....	1	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2	
Averages..	21.4	20.5	20.5	20.7	19.9	19.5	19.9	18.7	19.5	19.4	19.6	19.1	21.0	18.8	18.3	17.3	18.8	17.6	16.4	17.0	17.0	17.0	16.6	17.2	16.6	16.5	16.6	273

$$[o] = 18.6$$

$$a = 20.6$$

$$[ol] = -24.49$$

$$b = -0.064$$

$$[l] = 31$$

$$t = 74$$

$$[l^2] = 441.96$$

TABLE 2

SEASONAL DISTRIBUTION OF FLOWER NUMBER PER HEAD FOR PLANT E_3 OF BARBE DE CAPUCIN THREE YEARS OLD. DATA FOR 1914

Number of flowers per head	July								August											September											October				Total		
	10	11	17	18	20	22	27	30	1	4	6	10	12	15	17	19	21	24	26	31	3	8	10	12	15	17	22	24	26	28	30	2	5	7		9	
12	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	
13	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	1	1	
14	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	1	..	2	2	
15	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	1	..	1	..	1	..	..	..	..	1	..	1	..	5	7
16	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	1	..	..	..	..	1	1	..	2	1	..	..	..	..	..	7	24	
17	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	1	2	..	1	..	..	3	2	3	1	1	1	2	..	3	1	..	1	34	101	
18	..	..	..	..	..	..	..	..	..	2	..	..	..	..	..	1	4	1	2	3	2	..	1	..	1	1	2	1	4	2	..	2	..	5	92		
19	..	..	1	1	..	1	4	2	2	1	2	3	3	4	3	1	2	1	4	1	4	5	3	7	4	4	4	7	4	1	4	5	6	5	2	48	
20	..	..	4	5	3	4	3	6	4	3	2	3	5	3	6	2	1	..	3	5	3	3	2	2	1	4	1	..	2	5	..	3	2	1	92		
21	4	2	4	1	6	3	2	1	2	4	6	4	2	2	..	2	1	..	..	..	1	1	..	..	..	..	..	..	..	..	..	..	..	..	48		
22	..	..	1	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2		
23	1	..	..	..	1	..	..	..	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4		
Av.	21.4	21.0	20.5	20.0	20.7	20.6	19.8	19.9	20.6	19.9	20.4	20.1	19.9	19.5	19.9	19.9	18.4	17.7	19.1	18.4	19.3	19.6	18.1	18.8	17.9	18.9	18.0	18.6	18.2	18.8	17.6	18.7	19.0	17.9	17.7	321	

[o] = 19.2

a = 20.7

[ot] = -24.36

b = -0.032

[t] = 47

t = 91

[t²] = 801.71

TABLE 3

SEASONAL DISTRIBUTION OF FLOWER NUMBER PER HEAD FOR FIRST YEAR OF BLOOM OF AN F_1 GENERATION PLANT ($E_{22} \times A$)—10-ser. I, no. 5, DERIVED FROM A CROSS BETWEEN A PLANT OF BARBE DE CAPUCIN (E_{22}) AND THE WILD PLANT (A). DATA FOR 1915

Number of flowers per head	September																				October							November		Total
	4	6	7	8	9	10	11	13	14	15	16	17	20	22	23	24	25	27	28	29	6	9	13	16	19	22	26	1	4	
15	...	...	1	...	...	3	2	...	1	...	1	...	...	1	...	...	1	...	...	...	1	...	1	1	1	...	...	...	1	15
16	...	4	1	3	2	5	4	2	2	2	2	3	3	1	1	1	3	...	...	3	3	3	3	5	...	1	...	...	1	58
17	...	3	4	3	4	1	4	4	4	6	6	4	2	5	2	3	4	6	5	3	3	4	4	2	2	...	2	2	3	95
18	1	3	2	1	1	1	...	2	3	1	1	3	3	3	4	4	1	2	4	2	1	2	1	1	1	1	1	...	...	50
19	...	...	...	3	2	...	...	2	...	1	...	...	4	...	3	2	1	2	1	2	...	1	...	...	...	2	2	...	...	28
20	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	2
Averages..	18.0	16.9	16.9	17.4	17.6	16.0	16.2	17.4	16.9	17.1	16.7	17.0	17.6	17.0	17.9	17.7	16.8	17.6	17.6	17.3	16.9	17.1	16.6	17.3	16.7	18.0	17.7	17.0	16.4	248

$$[o] = 17.2$$

$$a = 17.1$$

$$[ot] = +1.33$$

$$b = +0.004$$

$$[t] = 29$$

$$t = 61$$

$$[t^2] = 310.79$$

the first day of blooming, b the calculated rate of decrease per day, and t the number of days the plant was in flower. $[o]$ represents the average flower number of the plant, calculated as are all the other values, from data collected throughout the flowering period.

Exceptions to the general rule of seasonal decrease occur. One of these is indicated in the performance record given in TABLE 3. The marked feature here is the decided uniformity in both range and average number of flowers per head throughout the entire period of bloom.

The plant here considered (TABLE 3) bloomed for a period of two months. The total number of heads counted was 248. The partial variability seen in the range of 15 to 20 was quite indiscriminate and coëxistent as to time. As the season advanced there was no appreciable change and the computed value for the rate of decrease is $+0.004$, a slight increase.

Data of another plant showing no intraseasonal decrease are presented in TABLE 4. Here there is, as in TABLE 3, no noticeable change in the general average or range from day to day, except for a few irregularities at the beginning and end of bloom in which the values usually obtained are reversed; the very lowest numbers per head appearing on the first two days of bloom.

In a few cases there is a decided though small increase from the beginning to the end of the season. The greatest increase observed was $+0.025$. In all these cases the plants had a low flower number throughout the season. TABLE 3I gives data for one of these plants.

A further variation in seasonal performance is shown by data of TABLE 15. Here there is a marked decrease both in the range and in the average of flowers per head, but the lower numbers of the range remain quite the same throughout; the shifting involves chiefly the higher numbers.

B. *Interannual partial variability.*

The collection of data from the same plant in successive years makes possible a comparison of the performance of an individual in different years in which the seasonal and growth conditions may be different, and in which the different ages of the plant may also give differences in vigor involving differences in time of blooming, all influencing the performance of the season.

TABLE 4

SEASONAL DISTRIBUTION OF FLOWER NUMBER PER HEAD FOR FIRST YEAR OF BLOOM OF A F_1 GENERATION PLANT ($E_{22} \times A$)—10—*ser. I*, no. 4, DERIVED FROM A CROSS BETWEEN A PLANT OF BARBE DE CAPUCIN (E_{22}) AND THE WILD PLANT (A). DATA FOR 1915

Number of flowers per head	September																				October										Total
	8	9	10	11	13	14	15	16	17	18	20	22	23	24	25	27	28	29	30	1	4	6	9	13	16	19	22	26			
12	1	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2		
13	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	—		
14	1	1	.....	.....	.....	.....	.....	1	1	.....	.....	.....	.....	1	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	6		
15	.....	.....	2	1	3	5	3	4	3	1	4	1	3	1	.....	.....	2	6	.....	1	2	1	1	1	1	1	1	2	50		
16	1	2	.....	3	3	3	4	1	4	1	4	2	3	.....	7	2	3	3	5	6	2	2	4	2	1	1	3	1	73		
17	3	2	1	1	1	2	3	3	2	6	2	4	4	5	2	6	5	1	3	3	3	5	3	2	7	.....	3	6	88		
18	.....	.....	.....	2	2	.....	.....	1	.....	2	.....	3	.....	3	.....	2	.....	.....	2	1	1	2	2	.....	.....	.....	.....	.....	23		
19	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2	.....	.....	.....	.....	.....	1	1	4		
20	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1		
Averages	15.3	15.2	15.3	17.0	16.2	15.7	16.0	15.9	15.7	16.9	15.8	16.9	16.1	16.8	17.0	17.0	16.3	15.5	16.7	16.4	16.9	16.8	16.6	16.2	16.7	15.5	16.5	16.7	247		

$$[o] = 16.5$$

$$a = 16.5$$

$$[ol] = +2.19$$

$$b = +0.009$$

$$[t] = 23$$

$$t = 48$$

$$[t^2] = 205.29$$

TABLES 5, 6, and 7 present data for the same wild white-flowered plant (*A*) for three successive years (1913, 1914, and 1915). The age of this plant when transplanted in 1911 from Wisconsin to the experimental garden was unknown. There has been no very marked difference in its general vigor and habit of growth in the five years that it has been under observation, except that in 1914 part of the roots which were inadvertently somewhat exposed were killed by winter freezing and there were fewer main branches produced from the cluster of roots.

The performance of this plant (*A*) in each of the three successive years shows a seasonal decrease that is quite characteristic of the species. There is also rather close agreement in the ranges of partial variability, these being 21-13, 22-15, 22-12. The average number per head and the standard deviation are also quite uniform as follows: 1913, 17.2 ± 1.79 ; 1914, 17.8 ± 1.41 ; 1915, 17.3 ± 1.72 . There is also rather close agreement in the values for the first date of blooming (*a*), but there was a considerable increase in the length of the flowering period, (*t*) in 1915 over that of the previous years. The rate of decrease (*b*) was lowest in 1915. The significance of these facts and the means of proper comparison of such data will be discussed presently.

The principal interannual partial variability is seen in the length of the blooming period. When this is considerably shorter, as in the year 1914, and the total amount of decrease remains much the same, the rate of decrease (*b*) is necessarily more marked.

The wild white-flowered plant considered above was grown from roots obtained in the field and its growth and vigor were much more uniform in successive years than is the growth of plants grown from seed. The latter, as a rule, exhibit in the second year of growth a marked increase in general vigor as measured by the number and size of the main stems, which gives a corresponding extension of the flowering period with the production of more flowers.

These aspects of interannual partial variability may be illustrated by TABLES 8, 9, and 10, which present the data collected from a plant in the first, second, and third year of growth.

The records of this plant in the first, second, and third years of growth agree in giving lower numbers per head as the

TABLE 5

SEASONAL DISTRIBUTION OF FLOWER NUMBER PER HEAD FOR A WILD WHITE-FLOWERED PLANT (A). DATA FOR 1913

Number of flowers per head	June		July												August												September		Total
	27	30	2	5	7	8	10	12	15	17	21	26	28	30	1	4	6	11	15	18	20	23	26	28	30	2	11		
13	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	2	
14	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	1	2	1	1	.....	4	4	1	2	.....	.....	17	
15	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	1	.....	.....	.....	1	1	1	3	5	6	3	5	5	5	5	.....	42	
16	.....	.....	.....	1	1	.....	2	.....	1	2	2	4	.....	2	2	1	3	3	2	3	3	3	.....	2	2	4	.....	43	
17	.....	.....	1	2	1	.....	1	1	2	1	2	1	.....	5	4	4	3	2	4	1	2	.....	1	3	.....	1	3	45	
18	.....	.....	1	5	4	1	4	5	3	5	2	3	.....	2	3	2	1	1	.....	.....	.....	.....	.....	.....	.....	.....	1	43	
19	1	2	7	2	5	6	3	4	4	1	4	1	1	1	1	.....	.....	1	.....	1	.....	.....	.....	.....	.....	.....	.....	45	
20	6	1	.....	.....	.....	5	.....	1	.....	1	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	15	
21	.....	.....	3	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	4	
Averages.....	19.9	19.3	19.3	17.8	18.2	19.5	17.8	18.5	18.4	17.8	17.5	17.2	19.0	17.2	17.3	16.2	16.2	16.2	15.9	15.7	15.6	14.9	14.5	15.6	15.0	15.6	17.2	256	

$$[o] = 17.2$$

$$a = 19.2$$

$$[ol] = -28.61$$

$$b = -0.059$$

$$[l] = 34$$

$$t = 76$$

$$[l^2] = 481.22$$

TABLE 6

SEASONAL DISTRIBUTION OF FLOWER NUMBER PER HEAD FOR A WILD WHITE-FLOWERED PLANT (A). DATA FOR 1914

Number of flowers per head	July					August										September			Total
	18	20	22	27	30	3	5	7	11	15	19	21	25	26	28	2	4	10	
15	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	2	1	1	1	2	1	9
16	.....	.....	.....	.....	1	.....	.....	2	.....	1	1	1	.....	2	1	2	1	.....	12
17	.....	.....	1	1	.....	1	.....	1	4	4	4	4	4	4	1	2	2	.....	33
18	1	1	4	1	1	5	.....	3	3	2	5	3	3	2	5	1	.....	.....	40
19	.....	5	4	6	5	2	7	4	4	3	.....	1	1	1	.....	.....	.....	.....	43
20	.....	3	.....	2	3	2	2	.....	.....	.....	.....	.....	.....	1	.....	.....	1	.....	14
21	.....	1	1	.....	.....	.....	1	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	4
22	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1
Averages.	18.0	19.4	19.0	18.9	18.9	18.5	19.4	18.2	18.0	17.7	17.4	17.2	17.1	17.3	17.3	16.5	16.7	15.0	156

$$[o] = 17.8$$

$$a = 19.3$$

$$[ol] = -15.67$$

$$b = -0.059$$

$$[l] = 25$$

$$t = 54$$

$$[l^2] = 263.72$$

TABLE 7

SEASONAL DISTRIBUTION OF FLOWER NUMBER PER HEAD FOR A WILD WHITE-FLOWERED PLANT (A). DATA FOR 1915

Number of flowers per head	July								August									September							October								Nov.	Total		
	8	12	15	17	20	23	26	30	2	5	9	13	16	19	20	24	27	31	2	4	8	18	23	25	28	4	7	11	14	18	21	25	28		4	
12	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
13	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
14	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	1	..	..	..	..	1	..	3	
15	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	3	..	..	..	1	..	1	..	..	..	..	1	..	3	2	3	2	1	18	
16	..	..	1	..	1	..	..	..	1	1	..	1	3	..	..	2	3	2	..	..	1	1	1	1	1	..	1	1	..	..	1	..	1	..	24	
17	..	2	2	3	1	1	..	3	2	..	1	3	4	..	1	4	2	2	..	1	3	1	1	1	2	..	1	1	..	..	..	2	1	45		
18	..	1	..	2	..	2	1	..	2	2	4	6	..	1	..	2	2	..	..	1	..	..	..	..	..	1	..	1	1	..	..	..	..	..	29	
19	..	1	3	2	8	4	4	6	4	1	3	..	2	..	1	..	..	..	..	..	1	..	..	..	..	2	..	..	..	1	..	..	..	..	43	
20	1	3	2	2	..	1	4	1	..	3	1	..	..	..	1	1	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	21		
21	..	1	2	1	..	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	6		
22	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1		
Averages...	20.0	19.0	19.1	18.6	18.5	19.1	19.6	18.5	17.7	18.7	18.4	17.5	17.1	18.0	18.7	17.3	16.3	17.2	14.0	15.0	17.3	16.0	16.5	16.0	16.7	18.7	16.5	16.0	18.0	16.0	15.3	15.0	15.7	16.0	191	

$$[o] = 17.3$$

$$a = 19.0$$

$$[ol] = -38.60$$

$$b = -0.031$$

$$[l] = 55$$

$$l = 119$$

$$[l^2] = 1234.47$$

TABLE 8

SEASONAL DISTRIBUTION OF NUMBER OF FLOWERS PER HEAD FOR FIRST YEAR OF BLOOM OF AN F_1 GENERATION PLANT ($E_3 \times A$) no. 7 DERIVED BY CROSSING A PLANT OF BARBE DE CAPUCIN (E_3) AND THE WILD PLANT (A). DATA FOR 1913

Number of flowers per head	August									Total
	6	8	11	14	19	21	26	28	30	
16	.....	.....	.....	.....	.....	.....	.....	.....	1	1
17	.....	.....	.....	.....	2	.....	.....	1	2	5
18	2	3	2	3	3	5	2	6	3	29
19	6	6	4	6	5	5	2	3	1	38
20	2	1	3	2	.....	.....	.....	.....	.....	8
21	.....	.....	1	.....	.....	1	.....	.....	.....	2
Averages.....	19.0	18.8	19.3	18.9	18.3	18.7	18.5	18.2	17.6	83

$$\begin{aligned}
 [o] &= 18.6 & a &= 19.1 \\
 [ot] &= -3.17 & b &= -0.045 \\
 [t] &= 12 & t &= 24 \\
 [t^2] &= 69.89
 \end{aligned}$$

season advanced. The range of intraseasonal partial variability was slightly increased in successive years, but there are very marked differences in the length of the blooming period, in the total number of flowers produced, and in the rate of decrease. The length of blooming period in the first year of bloom for this plant was rather below that of the average one-year-old plant. The average number of flowers per head for 1913 is 18.6, for 1914 it is 19.0, and for 1915 it is 18.7. The values of the first date of bloom are 19.1, 20.9, and 19.9. Aside from the rate of decrease the various values are not widely different. In this respect the plant in question is one of the most uniform that we have studied, exhibiting, perhaps, the least interannual variability with respect to values $[o]$ and a .

The interannual partial variability was usually more pronounced than in the plant noted above. Frequently the annual performance was quite divergent in nearly all respects. One of the most marked of such cases is seen in the plant for which data are given in TABLES 11, 12, and 13.

In the first year of growth (TABLE 11), this plant exhibited a rather short period of bloom, the number of flower heads produced was low; the range was only 20-17. In the second year (TABLE 12), the period of bloom was much extended, the total production

TABLE 9

SEASONAL DISTRIBUTION OF NUMBER OF FLOWERS PER HEAD FOR THE SECOND YEAR OF BLOOM (1914) FOR THE PLANT ($E_3 \times A$) no. 7. DATA FOR FIRST YEAR OF BLOOM GIVEN IN TABLE 8

Number of flowers per head	July					August											September											Total
	18	20	23	29	31	3	5	7	10	13	15	18	20	24	26	28	1	4	8	10	12	14	16	19	21	24	26	
14																			1									1
15																		1							1		1	3
16	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	1	1	.....	.....	.....	.....	1	.....	1	.....	1	.....	1	.....	2	9	
17	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3	2	2	1	1	1	2	.....	1	1	.....	.....	.....	2	1	17	
18	.....	.....	.....	.....	.....	.....	.....	.....	2	1	5	1	1	2	4	7	2	3	1	.....	1	1	.....	1	.....	.....	32	
19	.....	.....	1	3	2	3	1	6	3	3	1	3	3	3	1	2	1	1	.....	1	1	2	.....	.....	.....	.....	41	
20	1	.....	3	6	2	3	3	4	3	6	2	2	3	3	1	1	1	2	.....	.....	.....	.....	.....	1	.....	1	48	
21	2	3	4	1	6	3	6	1	.....	.....	2	.....	1	.....	2	.....	2	1	1	.....	.....	.....	.....	.....	.....	.....	35	
22	1	3	1	.....	.....	1	1	.....	.....	.....	1	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	9	
23	.....	1	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2	
24	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	
Averages.....	21.6	21.7	20.8	19.8	20.4	20.2	20.6	19.5	18.8	19.5	19.4	18.2	18.7	18.7	19.2	18.3	19.1	18.1	17.7	19.0	17.3	18.3	17.0	20.0	16.3	18.0	16.0	198

$[o] = 19.0$ $a = 20.9$

$[ol] = -23.79$ $b = -0.053$

$[l] = 36$ $t = 70$

$[l^2] = 443.11$

TABLE 10

SEASONAL DISTRIBUTION OF NUMBER OF FLOWERS PER HEAD FOR THE THIRD YEAR OF BLOOM (1915) FOR THE PLANT ($E_3 \times A$) no. 7. DATA FOR FIRST AND SECOND YEARS OF BLOOM GIVEN IN THE TWO PRECEDING TABLES

Numbers of flowers per head	July										August										September										October								November				Total
	2	6	9	12	15	19	21	23	28	62	2	6	10	13	17	19	20	24	27	31	2	4	8	11	15	18	23	25	28	4	7	11	14	18	21	25	28	1	4	8	11		
13	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
14	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	2	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	5
15	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	1	2	..	..	..	..	..	..	..	..	1	..	..	..	..	2	..	..	8	
16	..	..	..	..	..	1	..	..	..	..	1	..	..	..	1	..	..	1	1	1	1	2	1	1	3	1	1	5	..	1	..	2	..	..	..	..	1	..	1	..	25		
17	..	..	..	..	1	..	..	1	..	..	1	1	2	1	..	2	1	3	4	3	3	2	3	2	1	1	1	1	1	3	2	..	3	..	..	..	2	..	..	..	44		
18	..	..	1	..	..	1	1	1	2	1	1	..	2	3	2	1	..	1	2	2	2	3	3	3	..	5	3	1	3	1	..	..	3	4	4	1	1	1	..	1	..	60	
19	1	..	..	3	1	3	5	2	3	3	4	5	1	3	3	..	1	5	4	3	2	1	1	..	2	1	3	2	6	1	1	2	2	2	3	1	1	1	2	2	..	86	
20	..	..	2	4	4	2	1	1	4	3	5	2	3	..	4	1	1	3	..	..	2	1	2	1	..	..	1	..	..	1	1	2	2	1	2	4	..	..	..	1	..	60	
21	..	1	..	3	1	4	1	3	1	2	..	1	3	1	..	..	..	..	..	..	..	..	1	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	1	..	24		
22	..	3	6	..	1	..	..	2	..	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	14		
23	..	2	1	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4		
24	..	3	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4		
25	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1		
Averages..	19.0	23.0	21.3	20.0	20.6	19.9	18.4	20.0	19.4	19.9	19.4	18.9	19.5	18.8	19.0	18.0	18.2	19.0	17.9	17.7	18.1	17.6	17.3	17.6	16.6	17.2	17.2	17.3	18.5	17.8	18.2	18.3	18.3	18.6	18.4	19.5	16.8	18.5	16.8	19.2	20.0	336	

$$[o] = 18.7$$

$$a = 19.9$$

$$[ol] = -25.65$$

$$b = -0.018$$

$$[l] = 64$$

$$t = 131$$

$$[l^2] = 1493.19$$

TABLE 11

SEASONAL DISTRIBUTION OF NUMBER OF FLOWERS PER HEAD FOR THE FIRST YEAR OF BLOOM OF AN F_1 GENERATION PLANT ($C \times E_{22}$) no. 1 DERIVED BY CROSSING A WILD PLANT (C) AND A PLANT OF BARBE DE CAPUCIN (E_{22}). DATA FOR 1913

Number of flowers per head	August									September			Total
	7	8	13	14	16	19	25	27	30	13	23	29	
17	.....	.....	.....	.....	.....	2	.....	1	.....	2	1	.....	6
18	1	.....	2	1	1	2	.....	3	.....	1	.....	1	12
19	1	4	3	2	4	5	8	4	5	7	7	.....	50
20	3	2	1	4	3	1	2	2	4	.....	.....	.....	22
Averages.....	19.4	19.3	18.8	19.4	19.3	18.5	19.2	18.7	19.4	18.5	18.7	18.0	90

$$\begin{aligned}
 [o] &= 18.9 & a &= 19.2 \\
 [ot] &= -5.00 & b &= -0.016 \\
 [l] &= 19 & l &= 53 \\
 [l^2] &= 285.75
 \end{aligned}$$

of heads greatly increased, the range of flowers per head was 22-13, and there was a rather uniform and gradual rate of decrease. For the third year of bloom (TABLE 13), the period of bloom and range of partial variability were quite as in the previous year, but there were irregularities in the decrease in that the lowest numbers per head were reached in the latter part of September followed by a rather decided increase in number per head. For the successive years the numbers for average flowers per head $[o]$ are 18.9, 18.3, and 17.9; the values for the first day of bloom (a) are 19.2, 21.8, and 18.5, and the values for rate of decrease are -0.016 , -0.068 , and -0.028 . Both the average number per head $[o]$ and the value for the first day of bloom (a) are decidedly lower in the third year.

The interannual variation in regard to the intraseasonal variabilities was marked in the case of a plant for which data are presented in TABLES 14 and 15, and which have already been referred to as unusual types of interseasonal performance. Here the behavior in the first and second years of growth involve marked differences in the decrease and range. In the first year the daily range and average remained quite the same, in the second year there was a decided decrease in average, but the decrease in range was seen only in the higher number. The values of the number for first day of blooming, 15.3 and 17.1, are widely different, as are the rates of decrease $+0.001$ and -0.054 . However, the averages for flower number per head are quite identical, 15.3 and 15.8.

TABLE 12

SEASONAL DISTRIBUTION OF NUMBER OF FLOWERS PER HEAD FOR THE SECOND YEAR OF BLOOM (1914) FOR THE PLANT ($C \times E_{22}$) no. 1.

DATA FOR FIRST YEAR GIVEN IN TABLE 11

Number of flowers per head	July						August											September											October											Total
	17	20	23	26	30	31	4	6	8	13	15	18	22	26	28	29	5	7	8	10	12	14	16	19	22	24	26	29	1	3	5	7	9	13	15	20	22	27		
13	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	1	..	2		
14	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	1	3			
15	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	1	1	1	..	1	1	2	1	3	1	1	1	16			
16	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3	..	..	2	..	..	..	..	2	3	3	..	1	1	..	2	5	1	..	23			
17	..	..	..	..	..	..	..	..	..	..	..	..	2	..	..	..	..	3	1	3	1	3	1	4	3	..	4	1	1	3	1	2	..	..	..	..	33			
18	..	..	..	..	..	..	..	..	..	1	1	..	..	..	..	..	2	2	3	..	1	2	2	1	3	4	1	2	..	1	..	..	..	..	..	..	26			
19	..	..	..	2	2	..	1	..	..	5	1	8	8	4	5	3	12	5	4	6	5	4	1	4	3	2	1	2	2	1	..	..	1	..	..	92				
20	..	1	..	3	2	3	3	4	2	2	3	4	2	5	2	4	2	1	2	1	1	1	1	1	..	1	..	..	..	..	..	..	..	..	..	51				
21	2	4	5	5	8	1	6	6	7	3	1	1	..	..	1	3	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	54				
22	..	5	4	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10				
Averages....	21.0	21.4	21.2	20.3	20.5	20.6	20.5	20.6	20.8	19.8	19.7	19.3	19.2	19.1	19.0	20.0	19.1	17.9	18.7	18.5	18.2	18.3	18.4	18.2	17.7	17.7	16.8	17.4	17.5	17.0	15.4	16.3	16.0	15.4	15.5	14.5	14.0	14.0	310	

[o] = 18.3

a = 21.8

[ot] = - 57.08

b = - 0.068

[t] = 52

t = 102

[t²] = 842.00

TABLE 13

SEASONAL DISTRIBUTION OF NUMBER OF FLOWERS PER HEAD FOR THE THIRD YEAR OF BLOOM (1915) FOR THE PLANT ($C \times E_{22}$) no. 1. DATA FOR FIRST AND SECOND YEARS GIVEN IN TWO PRECEDING TABLES

Number of flowers per head	June	July											August											September											October							Total
	29	2	6	9	12	15	17	21	23	26	28	31	5	7	10	13	16	18	21	25	28	1	2	4	8	11	15	18	23	25	28	4	7	11	14	18	21	25				
12		..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	8	
13		..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	4	2	...	...	...	...	...	...	...	...	...	...	2		
14		..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	1	2	1	3	2	1	1	1	1	1	...	1	...	...	...	...	...	15	
15		..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	2	1	1	1	..	..	2	...	3	2	4	3	2	5	1	1	1	...	...	...	...	...	29	
16		..	..	..	..	1	..	2	3	1	1	1	..	1	..	1	2	4	3	1	2	2	3	3	4	3	...	2	1	4	5	1	1	4	1	2	3	2	64			
17		..	1	..	3	2	..	3	5	3	4	8	8	7	6	3	4	3	5	2	4	4	4	5	2	4	2	...	...	...	1	...	...	1	...	2	1	2	99			
18		1	6	5	7	6	6	5	2	4	4	1	1	2	3	2	1	1	1	1	2	3	2	1	...	1	1	...	...	...	1	...	...	...	1	...	1	72				
19		..	3	5	..	1	4	..	..	2	1	1	1	..	1	3	1	..	..	..	1	..	..	..	...	...	...	...	...	...	...	1	...	...	...	...	...	...	26			
20		1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2			
21	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	..	..	..	..	..	..	..	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4			
22		..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1			
Averages...	21.0	19.0	18.2	18.5	17.7	17.7	18.4	17.3	16.9	17.7	17.5	17.2	17.3	17.1	17.5	18.1	18.0	16.2	16.8	16.6	17.0	16.9	17.2	16.5	15.3	16.1	15.2	14.2	14.6	15.0	15.9	15.0	16.7	15.7	15.5	17.2	16.2	16.8	322			

[o]

=

17.9

[ol]

=

- 33.46

[t]

=

56

[t²]

=

1226.37

a

=

18.5

b

=

- 0.028

t

=

118

TABLE 14

SEASONAL DISTRIBUTION OF NUMBER OF FLOWERS PER HEAD FOR THE FIRST YEAR OF BLOOM OF AN F_2 GENERATION PLANT ($E_{22} \times A$)-10-no.
17 DERIVED FROM A CROSS BETWEEN A PLANT OF BARBE DE CAPUCIN (E_{22}) AND A WILD PLANT (A). DATA FOR 1915

Number of flowers per head	September														October												November			Total
	14	15	16	17	18	20	22	23	24	25	27	28	29	30	1	4	6	7	8	9	11	13	16	19	22	26	1	4	8	
12	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
13	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	1	...	...	...	...	...	...	1	1	...	...	...	4
14	1	...	3	4	4	2	1	...	2	1	1	1	1	...	1	...	1	2	...	...	1	1	...	...	...	...	...	2	29	
15	6	8	3	2	2	3	3	4	4	4	6	6	5	6	8	5	5	5	5	5	4	5	9	1	4	1	3	...	2	124
16	2	2	3	4	4	2	3	4	2	4	...	2	2	4	1	2	1	2	...	3	2	3	1	4	...	2	...	1	1	61
17	...	...	...	...	...	2	3	2	2	1	1	...	2	...	...	3	...	...	...	...	...	1	...	1	...	...	...	...	...	18
18	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	2
Averages.	15.1	15.2	14.7	15.0	15.0	15.4	15.8	15.8	15.4	15.5	14.9	15.4	15.5	15.4	15.0	15.8	15.0	14.8	15.0	15.7	15.1	15.4	15.1	15.4	14.6	15.7	15.0	16.0	14.8	239

$$[o] = 15.3$$

$$a = 15.3$$

$$[ot] = +0.22$$

$$b = +0.001$$

$$[l] = 23$$

$$l = 52$$

$$[l^2] = 236.72$$

TABLE 15

SEASONAL DISTRIBUTION OF NUMBER OF FLOWERS PER HEAD FOR THE SECOND YEAR OF BLOOM (1916) FOR THE PLANT ($E_{22} \times A$)-10-no. 17. DATA FOR FIRST YEAR GIVEN IN TABLE 14

Number of flowers per head	July										August								Total
	5	7	10	13	15	18	21	24	27	29	1	4	7	11	15	18	25	28	
14	...	...	...	...	...	...	...	...	...	...	1	1	1	1	...	1	1	1	7
15	2	...	4	...	1	4	5	1	6	4	6	5	6	3	4	6	...	1	58
16	1	5	1	1	2	3	3	5	2	4	3	2	1	3	1	...	...	...	37
17	3	2	4	6	4	3	2	3	2	2	..	2	2	1	...	...	...	...	36
18	1	...	1	3	2	...	...	1	...	...	...	...	...	...	...	...	...	...	8
19	1	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3
20	1	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2
21	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
Averages	17.5	17.2	16.2	17.2	16.8	15.9	15.7	16.4	15.6	15.8	15.2	15.5	15.4	15.5	15.2	14.9	14.0	14.5	152

$[o] = 15.8$ $a = 17.1$

$[ot] = -13.90$ $b = -0.054$

$[t] = 24$ $t = 54$

$[t^2] = 261.11$

2. INDIVIDUAL VARIABILITY

The various types of intraseasonal variability noted above are in reality records of the performance of individual plants during a seasonal period of growth. The differences noted between them as individuals are, therefore, evidences of individual variability. Individuals may differ decidedly in respect to one or more values, total production of heads, average and range of number of flowers per head, or amount and rate of decrease. These differences may appear among plants of the same age.

The interannual variability and especially that seen in the first two years of growth indicates clearly that much individual variability may exist in plants of different ages.

The inter-relations of individual variability and partial variability are here very evident. Any estimate of the former involves the latter in one or in all its aspects. It seems, therefore, clear that the question of an adequate judgment of the individual must be based on full performance at least during one season of growth, and that the comparison of individuals should be made for plants of the same age.

II. STATISTICAL TREATMENT OF DATA

The various sources of partial variability considered above make clear some essentials in regard to the proper collection and utilization of data in order that they may reveal the nature of the character of flower number and its hereditary behavior. If the flower number per head fluctuated with much the same range from day to day, as it does for a few plants of chicory, the mean, the standard deviation, and the coefficient of variability would be quite sufficient to give an estimate of the individual and could be determined from rather random readings with the magnitude of error depending chiefly on the number of heads that were counted. But this is not the case with the majority of plants. The flower heads mature at different dates and the number per head, as a rule, decreases as the season advances. It will be shown later this is to some degree related to the position of the head on a plant.

The partial variations from day to day are not solely fluctuating. For most plants, as shown in TABLES 1, 2, and 41 the daily range of fluctuation changes in a somewhat uniform progression to lower values. It seems to the writers that this element of change should be recognized in any statistical treatment which attempts adequately to determine values for a plant as a whole.

In this investigation, instead of calculating the mean and the variability, as expressed either by the standard deviation or the coefficient of variability, and using these as expressions to characterize the flower number of an individual plant, the *flower number of the first day of bloom* and the *rate of change* have been calculated and used.

The latter expression, as will be seen more clearly presently, is calculated as the mean and the variability would be from all the data at hand. A starting point, a rate of change, and the length of time through which this change takes place, gives an index to the variability. Furthermore, one can find the average flower number for any one particular day (o_n for t_n), if the flower number is given for the first day of bloom and the rate of change following (either positive or negative). We may assume, for the present, that the rate of change is uniform and call it b , and we shall indicate the flower number for the first day of bloom (which is to be calculated) a .

It is obvious from such typical data as have been presented in the foregoing tables that the average flower number for any particular day (o_n for t_n , for example) involves the actual flower number on the first day of bloom plus the amount of change, either positive or negative, following that date. In respect to flower number in chicory the change is usually a decrease, and if this decrease be computed it can be expressed as a rate of change for the season and designated as the value b . The amount of change from the first day of bloom to any one particular day (after the plant has been in bloom t_n days for example) can be expressed by the number of days the plant has been in flower multiplied by the rate of change, as bt_n . According to this conception then $o_n = a + bt_n$, and the following series of linear equations will express the series of averages obtained from the actual observations day by day: $o_0 = a + bt_0 \dots o_n = a + bt_n$.

From the data the average of the flower number obtained from day to day can readily be determined. This value for the data collected for the plant E_3 (see TABLE I) arranged in the first column of TABLE 16 is 18.6.

The values of t are also known and can be expressed as deviations from the average time of blooming computed from the known dates of the collection of data. This average as given for plant E_3 in the second column of TABLE 16 is 30.7. Since this average is often a fraction the calculation may be simplified by measuring the different times of the collection of data from the integer nearest to the average so that $t_n = t + \tau_n$ when t is the integer nearest the average and τ_n is the deviation of t_n from this integer. If the difference between the true average and the integer used in the calculation be considered as d then the full value for the deviation from the true average is $\tau_n + d$.

The average of all the $(\tau + d)$'s must, of course, equal zero, because they express the plus and minus deviations from the true average. The average of all the τ 's equals $-d$. The equations then assume the form:

$$o_0 = a + b(t + d + \tau_0)$$

$$o_1 = a + b(t + d + \tau_1)$$

$$o_2 = a + b(t + d + \tau_2)$$

$$\dots \dots \dots$$

.

.

$$o_n = a + b(t + d + \tau_n)$$

The average of this series is $\bar{o} = a + b[t]$; because as shown above $[\tau] = -d$ and $+d - d = 0$.

The value of a thus becomes equal to $[\bar{o}] - b[t]$ and of these quantities $[\bar{o}]$ and $[t]$ are determined from the data and are known.

For the purpose of calculating the value of b another equation is needed and this may be obtained by multiplying each of the above series of equations by $\tau + d$. Since, however, d is the same value throughout we may ignore it and we have:

$$o_0 \tau_0 = \{a + b(t + d)\} \tau_0 + b\tau_0^2$$

$$o_n \tau_n = \{a + b(t + d)\} \tau_n + b\tau_n^2$$

Averaging and substituting $[\tau] = -d$,

$$2[\bar{o}\tau] = -d(a + bt) - bd^2 + b[\tau^2]$$

$$3[\bar{o}]d = d(a + bt)$$

Multiplying 1 by d gives 3

$$4[\bar{o}\tau] + d[\bar{o}] = b[\tau^2] - bd^2$$

Adding 2 and 3 gives 4

Solving this equation the value of b is obtained, and substituting the value of b in 1 gives the value of a .

In TABLE 16 are calculated the values of b and a for the plant E_3 in 1913 (see TABLE I for values of o) in order to illustrate the method employed.

It will be more apparent in the presentation of data that follows that differences in the rate of decrease throughout the season already noted in the general survey of intraseasonal partial variability are undoubtedly the source of greatest individual variability. The expression $[\bar{o}] = a + b[t]$ as developed above can be used to express the general behavior of an individual in respect to flower number, and from it are determined the values of a and b to be used in comparisons.

The values of a and b therefore may be discussed further. In the plant involved in TABLE 16 the value of b is -0.065 . This is the value of the amount of decrease per day estimated from all the observations. While the actual variation in the rate is more or less variable in the data as collected, there is much in the behavior to suggest that until more of the factors contributing to this are known and analyzed, it may be treated theoretically as a uniform rate in each plant, an assumption which will admit of the foregoing mathematical treatment.

TABLE 16

CALCULATION OF FLOWER NUMBER OF FIRST DAY OF BLOOM (a) AND SEASONAL RATE OF DECREASE (b) FROM THE DATA FOR A PLANT OF BARBE DE CAPUCIN (E_3) PRESENTED IN TABLE I

o	t	$\tau + d$	$o(\tau + d)$	$(d + \tau)^2$
+ 3.4	0	- 31	- 1054	961
2.5	1	30	750	900
2.5	2	29	725	841
2.7	5	26	702	676
1.9	7	24	456	576
1.5	11	20	300	400
1.9	13	18	342	324
0.7	15	16	112	256
1.5	18	13	195	169
1.4	20	11	154	121
1.6	23	8	128	64
1.1	25	6	66	36
3.0	26	5	150	25
0.8	28	3	24	9
0.3	30	1	3	1
- 0.7	33	+ 2	14	4
0.8	35	4	+ 32	16
0.4	37	6	24	36
1.6	40	9	144	81
1.0	44	13	130	169
1.0	47	16	160	256
1.0	50	19	190	361
1.4	55	24	336	576
0.8	60	29	232	849
1.4	64	33	462	1089
1.5	67	36	540	1296
1.4	74	43	602	1849
[o] 18.0 + 0.6	30.7		[ot] = - 29.49	[t^2] = 441.96
	[$\tau + d$] = 31 - 0.3			

Substituting in formula derived above

- (1) + 0.6 = $a + 31b$
 - (2) - 29.49 = + 0.3($a + 31b$) + 441.96 b - (0.09 b^2) (last value so small that it may be neglected)
 - (3) + 0.18 = + 0.3($a + 31b$)
 - (4) - 29.67 + 441.96 b
- $\therefore b = - 0.065$
 $a = 18.0 + 2.6 = 20.6$

The question will immediately arise whether the assumption of a uniform rate of decrease is justified. If there were only meager data at hand for each plant it would be necessary to use the mean and the standard deviation as values. In such cases it would be recognized that such values are not the most satisfactory expression of flower number, but that they are the best available from the material at one's disposal. In chicory, however, there

are sufficient data to enable the determination of a more adequate expression for the behavior with respect to flower number; namely, the theoretical value for the first day of bloom (a) and the rate of decrease per day (b).

It is, however, evident that the rate of decrease is influenced by a large number of factors such as length of blooming period, position of heads on branches, kinds of heads, whether terminal or lateral, etc., points which will be brought out later in the paper, and that it is in consequence not uniform throughout the season. The data, while sufficient to give us an approximate value for the rate of decrease, are not sufficient to determine it absolutely, and it must be borne in mind that the expression for flower number used in this paper is not considered to be absolute, but merely the most adequate to be obtained from the material at hand. This value can be determined from all the data in the manner developed above.

The value of a can also readily be determined on the basis of the observations. In the case of the data in TABLE 16, $a = 18.6 - [(-0.065) 31] = 20.6$. This is a computed value for the flower number of the first date of bloom.

It will be seen that two plants which start with the same flower number per head and show the same rate of decrease must have a different average number of flowers per head for the whole season if their blooming periods are of different lengths. The average will be lower the longer the blooming period. Just so the standard deviation will be the greater the longer the blooming period. On the other hand, if the two plants show differences in the rate of decrease the average number of flowers per head for the whole season may be the same in the two plants. The following comparison should make the point quite clear. The plant E_3 (TABLES 1 and 2) bloomed 74 days in 1913 with an average flower number for the season of 18.6 and a standard deviation ± 1.9 . In 1914 it bloomed 91 days with an average flower number of 19.2 and standard deviation of ± 1.5 . Does this mean that in 1914 E_3 started with a higher number of flowers per head than in 1913, and maintained this characteristic throughout the season, or was the starting point in the two years the same with a difference in the manner of decrease? In using the method described above, for

the plant E_3 for the year 1913, the number of flowers per head for the first day of bloom was 20.6 with a decrease of -0.064 per day; while for the year 1914 the average number of flowers for the first day of bloom was 20.7 with a rate of decrease of -0.032 . The higher average in 1914 was due to a slower rate of decrease. To illustrate this point further we may take the plant ($E_3 \times A$) no. 7 (TABLES 8 and 9) in 1913 and 1914. In 1913 the average was 18.6 with a standard deviation of ± 0.9 ; in 1914, 19.0 with a standard deviation of ± 1.7 . In 1913 the blooming period was 24 days; in 1914, 70 days. The averages are the same as for the plant E_3 , but the standard deviation is smaller for ($E_3 \times A$) no. 7 in 1913. The values for the first day of bloom and the rate of decrease show that the plants are different in respect to flower number. In the plant ($E_3 \times A$) no. 7 the difference between the rate of change in 1913 and 1914 is not very great. In 1913 it was -0.045 ; in 1914, -0.053 . The average flower number for the first day of bloom is, however, quite different for the two years. In 1913 it was 19.1; in 1914, 20.9. This together with the different length of blooming periods accounts for the differences in the values of a obtained for the plants E_3 and ($E_3 \times A$) no. 7.

III. DETAILED PRESENTATION OF DATA BEARING ON

I. RELATION OF LENGTH OF BLOOMING PERIOD TO RATE OF CHANGE

One of the most obvious facts brought out by the data is that in plants showing a seasonal decrease the rate of decrease is less the longer the blooming period. The following correlation table (TABLE 17) brings out this fact very clearly. The plants used are three-year-old F_1 plants, of which there are data for 110 plants.

For a further study of the relation of rate of decrease to length of flowering period these plants may be grouped as indicated. As there were rather few plants with short blooming periods, it was necessary to include in the first group all the plants that bloomed less than 60 to 100 days. This group consisted of 16 plants. There were only three plants that bloomed less than 60 days, so these were left out entirely. In order to have a sufficient number of plants in the fifth group those blooming from 130 to 150 days were here included.

The table shows that there is a considerable negative correlation between length of blooming period and rate of decrease. The high values for the rate of decrease all fall in the first group, that is the group containing the plants with the shortest blooming periods. The fifth group, which is the group of plants with the longest blooming period, has the lowest values for the rate of decrease.

TABLE 17

CORRELATION BETWEEN LENGTH OF BLOOMING PERIOD AND RATE OF DECREASE.
DATA FOR 110 F₁ PLANTS, 3 YEARS OLD

Days of bloom	Rate of decrease in units (×100)											Total	
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11		
40-50	.....	.....	.....	.....	.....	.....	I	.....	.....	.....	.....	I	.....
50-60	.....	I	I	.....	.....	.....	.....	.....	.....	.....	.....	2	.....
60-70	.....	.....	.....	.....	.....	.....	I	.....	.....	.....	.....	I	} I
70-80	.....	.....	.....	I	I	.....	.....	.....	.....	.....	I	3	
80-90	.....	.....	.....	I	I	2	.....	I	.....	I	.....	6	
90-100	I	.....	.....	.....	I	I	.....	I	I	I	.....	6	} 2
100-110	.....	2	I	5	I	5	I	.....	.....	.....	.....	15	
110-120	I	5	7	8	4	I	.....	.....	.....	.....	.....	26	
120-130	I	7	8	9	4	3	.....	.....	.....	.....	.....	32	} 4
130-140	.....	2	5	2	I	.....	.....	.....	.....	.....	.....	10	
140-150	.....	2	5	I	.....	.....	.....	.....	.....	.....	.....	8	
Total.	3	19	27	27	13	12	3	2	I	2	I	110	

$r = - 0.67$

The average flower number was calculated in successive twenty-day periods for each group. TABLE 18 gives the average flower number for these twenty-day periods. The five groups are very much alike, excepting that there is, perhaps, a somewhat greater decrease between the first and second twenty days in the plants

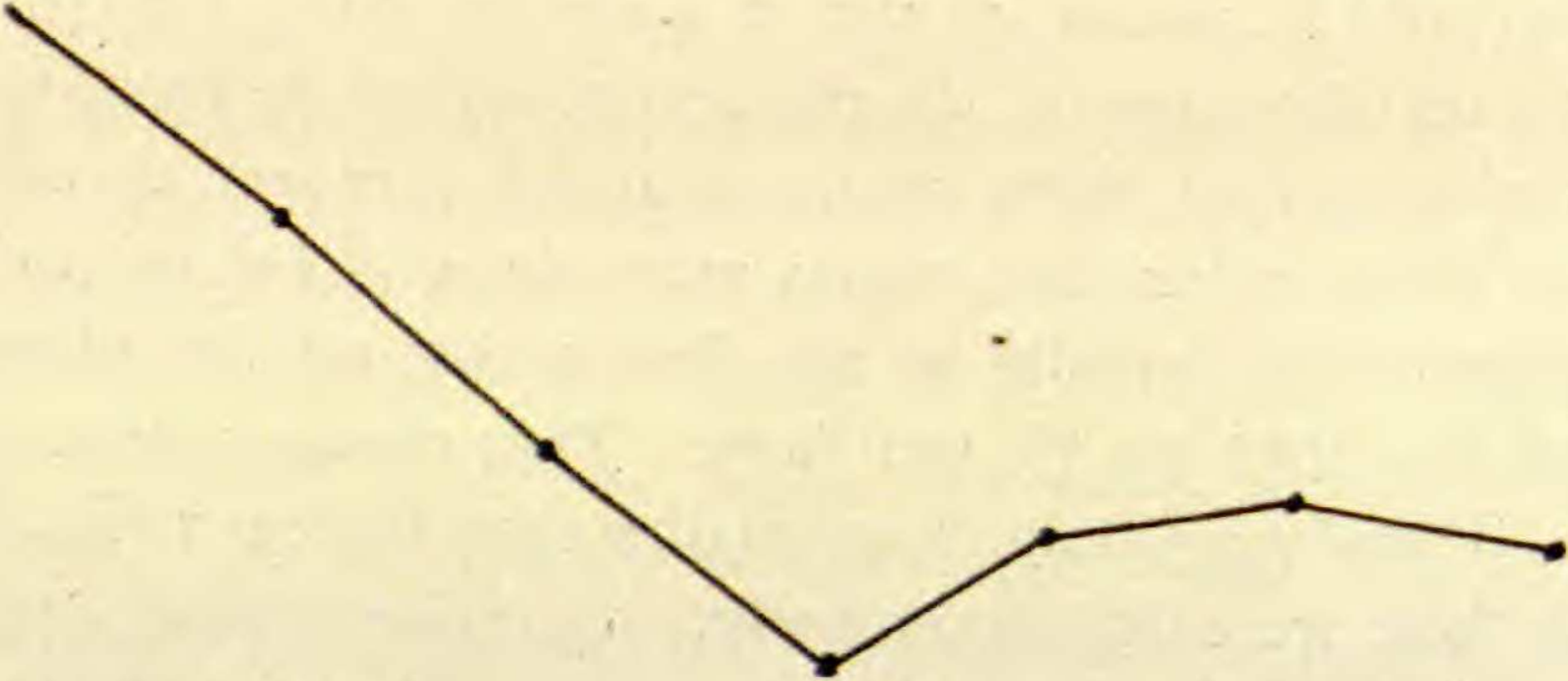


DIAGRAM ACCOMPANYING TABLE 18 SHOWING CURVE FOR AVERAGE DECREASE FOR SUCCESSIVE TWENTY-DAY INTERVALS OF BLOOM.

TABLE 18

AVERAGE FLOWER NUMBER AND AVERAGE VARIABILITY FOR SUCCESSIVE 20-DAY PERIODS OF BLOOM. DATA FOR 110 F_1 PLANTS, 3 YEARS OLD
(SAME AS PRESENTED IN TABLE 17)

	1			2			3			4			5			Average difference
	Up to 60 days			Up to 100 days			Up to 110 days			Up to 120 days			Up to 130 days			
	Average	Difference	Number of heads	Average	Difference	Number of heads	Average	Difference	Number of heads	Average	Difference	Number of heads	Average	Difference	Number of heads	
First 20 days....	20.5		2,257	20.3		2,195	19.9		3,608	19.7		4,536	20.3		2,428	.....
Second " "	19.5	-1.0	1,178	19.0	-1.3	1,053	19.0	-0.9	2,140	18.9	-0.8	2,678	19.4	-0.9	1,435	-0.94
Third " "	18.2	-1.3	666	18.0	-1.0	717	17.9	-1.1	1,627	17.6	-1.3	1,807	18.7	-0.7	1,010	-1.11
Fourth " "				17.1	-0.9	698	17.0	-0.9	1,209	16.8	-0.8	1,536	17.5	-1.2	1,096	-1.00
Fifth " "				17.8	+0.7	249	17.8	+0.8	849	17.1	+0.3	985	17.6	+0.1	839	+0.43
Sixth " "							17.6*	-0.2	337	16.5	-0.6	867	18.1	+0.5	729	0.00
Seventh " "													17.8*	-0.3	296	-0.30
	σ	Difference	Number of heads	σ	Difference	Number of heads	σ	Difference	Number of heads	σ	Difference	Number of heads	σ	Difference	Number of heads	Average difference
First 20 days....	± 1.91		2,257	± 1.82		2,195	± 1.73		3,608	± 1.98		4,536	± 2.02		2,428	.....
Second " "	± 1.51	-0.40	1,178	± 1.62	-0.20	1,053	± 1.63	-0.10	2,140	± 1.57	-0.41	2,678	± 1.41	-0.61	1,435	-0.34
Third " "	± 1.92	+0.41	666	± 2.00	+0.38	717	± 1.97	+0.34	1,627	± 1.91	+0.34	1,807	± 1.92	+0.51	1,010	+0.40
Fourth " "				± 2.10	+0.10	698	± 2.10	+0.13	1,209	± 2.03	+0.12	1,536	± 2.14	+0.32	1,096	+0.18
Fifth " "				± 1.77	-0.33	249	± 2.06	-0.04	849	± 1.95	-0.08	985	± 1.99	-0.15	839	-0.15
Sixth " "							$\pm 2.10^*$	+0.04	337	± 1.74	-0.21	867	± 1.80	-0.19	729	-0.12
Seventh " "													$\pm 1.65^*$	-0.15	296	-0.15

* Ten days

with short blooming periods. In the plants with the longest blooming periods, the greatest decrease comes between 40 and 60 days, while in the others it comes between 20 and 40 days. In the last column are given the average differences for the successive twenty-day periods. It will be seen that the greatest difference is between the first and second period, so that here the rate of decrease must be the greatest. Between the third and fourth period there is an increase in flower number rather than a decrease, and after that there is only a slight decrease, if any. The diagram of TABLE 18 illustrates this point. The differences between the averages of the different periods have been plotted and it will be seen that there is a marked change in the rate of decrease after the first eighty days. Plants that bloom eighty days and less will show a greater rate of decrease than those that bloom longer for the reason that there is a slight increase or no further decrease in flower number after the first eighty days. This accounts for the large negative correlation between rate of decrease and length of blooming period. This discussion also illustrates the fact that the range of variability in respect to high and low flower number per head is not very closely related to length of bloom.

The variabilities have also been calculated for the successive twenty-day periods (TABLE 18). The σ 's show a decrease, then an increase, and following this they again decrease. Since all the factors influencing flower number are not known, one cannot define the different variabilities exhibited by the different periods. We know, however, that there are sources of variability during the first period which do not exist later on, as, for instance, the coming into bloom of the different branches. The decrease in variability towards the end of the blooming season follows necessarily from the fact that there is a limit to the lowest number of flowers per head produced by a plant. The high numbers which appeared early in the season do not as a rule appear late in the season; the low numbers, however, appear early and do not decrease further as the season advances.

The range of variability for three-year-old F_1 plants and one-year-old F_3 plants for successive twenty-day periods is given in TABLE 19. These plants are reported in detail in TABLES 18 and 20.

TABLE 19

RANGE OF VARIABILITY FOR SUCCESSIVE 20-DAY PERIODS OF BLOOM. DATA FOR F_1 3-YEAR-OLD PLANTS (REPORTED IN TABLE 18). DATA FOR F_3 1-YEAR-OLD PLANTS (REPORTED IN TABLE 20)

		Range of variability	Difference	Number of plants
F_1	First 20 days	30-14	16	107
	Second " "	27-10	17	107
	Third " "	25-12	13	107
	Fourth " "	25-10	15	91
	Fifth " "	23-10	13	76
	Sixth " "	24-11	13	50
	Seventh " "	22-12	10	18
F_3	First 20 days	33-10	23	110
	Second " "	24- 9	15	97
	Third " "	23-11	12	78
	Fourth " "	23-10	13	39
	Fifth " "	20-12	8	12

This table shows that the lowest flower number on a plant may appear in the first or second twenty days of the blooming period while the highest number appears only in the beginning of the season and decreases as the season advances. This must, of course, result in a smaller variability for the end of the season and also explains why there is such a marked negative correlation between rate of decrease and length of the blooming period.

The period of bloom for plants in the first year of growth is shorter than in the succeeding years. There is, however, a similar negative correlation between rate of decrease and length of blooming period, as in the older plants discussed above. For the behavior of plants in the first year of bloom there are data on 110 of the F_3 plants, all blooming in the same year (1915). The plants, for convenience, have been grouped into five groups, each group blooming twenty days longer than the preceding. As shown in TABLE 20 the same sort of differences appear in successive twenty-day periods as in the older plants, that is, the differences are less or there may even be an increase in the later periods.

The variabilities for the F_3 plants are given in the same way as for the F_1 plants, and here too the σ 's are the greatest for the first twenty days.

From the foregoing discussion, it is clear that there is less difference between the averages and that the variabilities are lower for twenty-day periods after the first eighty days for the three-

TABLE 20

AVERAGE FLOWER NUMBER AND AVERAGE VARIABILITY FOR SUCCESSIVE 20-DAY PERIODS OF BLOOM. DATA FOR 110 F₃ PLANTS, ONE YEAR OLD

	Up to 20 days			Up to 40 days			Up to 60 days			Up to 80 days			Up to 100 days			Average Difference
	Average	Difference	Number of heads	Average	Difference	Number of heads	Average	Difference	Number of heads	Average	Difference	Number of heads	Average	Difference	Number of heads	
First 20 days.....	18.0	.....	1,359	17.5	.....	2,457	17.3	.....	5,626	17.8	.....	4,129	18.5	.....	1,860	.....
Second " ".....				16.4	-1.1	1,127	16.7	-0.6	2,777	17.1	-0.7	2,201	17.3	-1.2	1,069	-0.90
Third " ".....							15.9	-0.8	1,249	16.1	-1.0	1,133	16.2	-1.1	680	-0.97
Fourth " ".....										16.1	0.0	656	15.7	-0.5	460	-0.25
Fifth " ".....													15.9	+0.2	381	+0.20
	σ	Difference	Number of heads	σ	Difference	Number of heads	σ	Difference	Number of heads	σ	Difference	Number of heads	σ	Difference	Number of heads	Average Difference
First 20 days.....	± 2.11	.....	1,359	± 2.08	.....	2,457	± 1.84	.....	5,626	± 1.83	.....	4,129	± 2.02	.....	1,860	.....
Second " ".....				± 1.71	-0.37	1,127	± 1.71	+0.13	2,777	± 1.74	-0.09	2,201	± 1.73	-0.29	1,069	-0.16
Third " ".....							± 1.66	-0.05	1,249	± 1.61	-0.13	1,133	± 1.54	-0.19	680	-0.12
Fourth " ".....										± 1.71	+0.10	656	± 1.64	-0.10	460	+0.10
Fifth " ".....													± 1.46	-0.18	381	-0.18



DIAGRAM ACCOMPANYING TABLE 20 SHOWING CURVE FOR AVERAGE DECREASE FOR THE FIVE SUCCESSIVE TWENTY-DAY INTERVALS OF BLOOM.

year-old F_1 's and after the first sixty days for the one-year-old F_3 's. In other words, most of the decrease has taken place during eighty days in the first case and during sixty in the second. It is quite obvious then, when purely mathematically considered, that there should be a large negative correlation between rate of decrease and length of blooming period.

2. SIGNIFICANCE OF THE RANGE OF VARIABILITY IN FLOWER NUMBER PER HEAD

A question which arises in this connection, and which appears to be of considerable biological significance, is whether the total amount of decrease or the actual range in variation in flower number throughout the season bears any relation to the highest flower number in the plant. In other words, do plants with high flower number show a larger total decrease than those with low, or is the amount of decrease about the same in each? The question was suggested by the comparison given above of the data for different periods of bloom, when it became evident that the variability during the later periods was lower than that of the earlier.

The following tables, one for three-year-old F_1 plants and one for one-year-old F_3 plants (the same used above) will perhaps best

TABLE 21

RANGE OF VARIABILITY OF FLOWER NUMBER PER HEAD OF 106 THREE-YEAR-OLD PLANTS OF THE F_1 GENERATION

Number of plants	Maximum flower number	Minimum flower number		Difference between maximum and average minimum
		Range	Average	
1	30	—	15.0	15.0
2	29	13-12	12.5	16.5
3	28	17-14	15.3	12.7
5	27	15-12	14.2	12.8
14	26	16-12	14.0	12.0
8	25	17-13	14.2	11.8
17	24	15-11	13.8	10.2
19	23	16-10	12.6	10.4
21	22	17-11	12.9	9.1
13	21	16-11	13.2	7.8
3	20	13-11	12.0	8.0

answer the question. Here the total range from highest to lowest flower number has been recorded, the plants with the same highest

number are put in one group. The highest numbers for the 106 plants of TABLE 21 range from 30 to 20 and the lowest numbers from 16 to 10; for the plants of TABLE 22 the highest numbers range from 33 to 17 and the lowest from 17 to 9. For the plants as a whole there is therefore a greater range for the highest number per head than for the lowest number.

TABLE 22

RANGE OF VARIABILITY OF FLOWER NUMBER PER HEAD OF 189 ONE-YEAR-OLD PLANTS OF THE F_3 GENERATION

Number of plants	Maximum flower number	Minimum flower number		Difference between maximum and average minimum
		Range	Average	
1	33	—	13.0	20.0
1	27	—	13.0	14.0
5	26	15-13	14.4	11.6
3	25	15-14	14.7	10.3
9	24	15-13	13.8	10.2
25	23	16-10	13.6	9.4
41	22	17-10	13.9	8.1
48	21	17-11	13.5	7.5
36	20	15-9	12.9	7.1
11	19	13-11	12.0	7.0
8	18	14-10	11.9	6.1
1	17	—	11.0	6.0

The plants with highest numbers, however, show the greatest range of variability as their lowest numbers are as low as the majority of the plants with lowest values of the highest number. A glance at the TABLES 21 and 22 shows this point. Of three-year-old plants those with such high numbers as 30-26 have lowest numbers of 17-12, while those with high values at 22-20 range from 17-11. Of the one-year-old plants the ones with high values of 33-23 have low values of 16-10, while those of 22-17 have lowest values, ranging from 17 to 9. The extremes and the averages of the lowest numbers are quite the same irrespective of the higher values.

Different plants exhibit greater variation in respect to the highest number of flowers borne in any head than in regard to the lowest, and therefore an individual plant exhibits the greatest range if the highest number is high for that plant. The variabilities of individuals and of groups increase as the upper limits of flower number increase.

These facts have a special significance in suggesting that any evolutionary change that may have occurred or that may be now in progress in respect to flower number is affecting the high numbers more than the low. The numbers in the various classes, as revealed in TABLES 21, 22, and 23, indicate that there are few plants with extremes of highest flower value and that the greater number of plants of the general population as grown have intermediate values for the highest flower number. In other words, highest flower number exhibits fluctuating variation of greater extent than lowest flower number and is to a large measure independent of the latter. Data will be given later regarding the heredity of high values as expressed for a plant as a whole by values of a , and also as to the effect of selection on high or low values.

TABLE 23

RANGE OF VARIABILITY OF FLOWER NUMBER PER HEAD FOR 219 ONE-YEAR-OLD PLANTS OF THE F_4 GENERATION

Number of plants	Maximum flower number	Minimum flower number		Difference between maximum and average minimum
		Range	Average	
1	26	—	12.0	14.0
4	25	16-11	14.0	11.0
2	24	14-13	13.5	10.5
7	23	15-11	13.4	9.6
19	22	16-12	14.1	7.9
45	21	17- 9	13.4	7.6
61	20	15- 7	13.3	6.7
55	19	15-11	12.9	6.1
20	18	13-11	12.3	5.7
5	17	14-12	12.8	4.2

3. RELATION OF FLOWER NUMBER PER HEAD TO POSITION OF HEADS

A. *Descriptive studies regarding position.*

Early in the collection of data, it was observed that the first heads to bloom are, as a rule, situated on the uppermost branches, and also that the first head which opened on a branchlet or in a cluster of flower heads is the terminal one. This at once suggested that the seasonal decrease so uniformly observed may be related to a succession of bloom involving a periodicity between development of different main laterals and also between different secondary branches of main laterals.

As a rule chicory plants are much branched. Grown from seed there is in the first year a single main stem. In the variety "red-leaved Treviso" there is a rather uniform duplication of the single main stem, giving two stem elements usually quite pronounced but cohering strongly.

From the main axis numerous laterals arise which are further branched, producing bushy plants as shown in PLATES 10 and 11. All branches end in flower heads, but considerable variation exists in the development of the ultimate branches, not only for different individual plants but among the different branches of a single plant. In some plants many of the ultimate branches are elongated, giving a divaricate habit with many heads that appear solitary and decidedly terminal (PLATE 12, marked 1). Branches which are lateral to these are usually less elongated (PLATE 12, 2 on plate), so that the flower heads appear sessile, but these in turn may have further lateral but much reduced branches. Very often several branches constituting a system in the axil of a leaf are all much reduced so that several heads appear much branched and closely compacted, as shown at points indicated as 3 on PLATE 12. In some plants the ultimate branches are well developed and the clusters contain few heads involving only the last few ranks of ultimate branches. Such rather simple grouping is shown in PLATE 13, A, in the series of laterals, all from the same plant, which show a graded transition from a lateral with a terminal and three sessile laterals (1); to two laterals (3); to one lateral (4, 5, 6, and 7); the series illustrating successive stages of shortening of branches. B of the same plate has a somewhat more marked development of secondary laterals. In other cases there is little development of penultimate branches, so that clusters of numerous heads are frequent and the general branching is more sparse. The branches shown in the plate are near the apex of the main or large basal laterals; the larger main laterals near the base of a plant have larger laterals near their bases, which in turn duplicate the branching system of the more terminal parts of the main branches.

As all flower heads are in reality terminal for the particular branches, the distinction of terminal and lateral heads is purely a relative one. A terminal head blooms before a head that is

immediately lateral to it. Thus in PLATE 13 the heads marked *a* in each case bloom before the one (*b*) lateral to it with branches *A*, 1-3; however, *a* blooms first, but the next to bloom is *b*, the terminal of the most basal cluster rather than *c*, which is immediately below the head *a*. The same general behavior holds for such cases of reduced branching as are shown in *C* and *D* of PLATE 13.

B. Statistical studies regarding position.

A complete study of the flower number per head according to position of terminals and laterals for all parts of the plant would involve a series of numbering from all apices to base in succession for all branches. For plants of the simplest branching even, this would be a very involved study. However, some clue to the relationship between position, time of blooming, and flower number can be gained by a comparison of terminals with heads that are immediately lateral to them. Such data may be obtained without discrimination between various branches, or they can be obtained separately for each of the main lateral branches.

Data from the intensive study last mentioned above have been obtained from five plants. The flowers of the heads were counted and the data recorded with respect to position on the various branches. All heads were counted with the exception of those that opened on Sundays or on days of heavy rainfall so that the data are nearly complete for all flower heads.

The behavior of one of these plants is recorded in TABLE 24. The data were collected in 1915 from an F_1 plant of wild white $\times$ Barbe de Capucin, $\{(A \times E_3) \text{ no. } 4\}$, which was then three years old. The data are given for the unbranched portion of the terminal axis and for the various successive lateral branches. The numbers in Roman are averages for terminal heads, either solitary or in a cluster, and the numbers in italics are for laterals, the averages being computed for each day. The daily averages for terminals and laterals are given for all branches. In quite the same manner the performance of another plant, an F_3 of the cross wild white-flowered $\times$ Barbe de Capucin $\{(A \times E_{22}) - 9-4 - \text{no. } 14\}$ in the first year of bloom is presented in TABLE 25.

We may first consider the comparison of relative numbers and values for terminals and laterals as such as to time of development. For the plant reported in TABLE 24, no laterals opened during the

TABLE 24

SEASONAL DISTRIBUTION OF FLOWER NUMBER PER HEAD FOR THIRD YEAR OF BLOOM OF AN F_1 GENERATION PLANT ($A \times E_3$) no. 4, DERIVED BY CROSSING THE WILD PLANT (A) AND A PLANT OF BARBE DE CAPUCIN (E_3), DAILY AVERAGES ARRANGED ACCORDING TO POSITION OF BRANCH AND OF HEAD ON BRANCH. DATA FOR 1915. (TERMINALS, IN ORDINARY TYPE; LATERALS, IN ITALICS)

Branches starting at top	June		July																			August					
	29	30	1	2	3	6	7	8	9	10	12	13	14	15	16	17	20	22	26	27	29	31	5	6	7	10	16
Main				19.0	18.3	18.0			16.0				19.0														
									18.0	19.0	19.5	17.0		19.0		18.5	19.0			17.5	18.0						
			19.0				19.0																				
I																		19.0								15.0	
			19.0			20.0																					
2														19.0	19.0												
			19.0			19.0																					
3																										15.0	
		20.0				19.0						18.0															
4						18.0																					
		20.0			19.0																						
5											18.0																
	19.0				19.0				20.0																		
6																											
		20.0		17.0														15.0									
7									19.3		18.0								16.0			17.0					
			19.0	20.0			19.5																				
8							19.0	16.0			19.0	19.0		19.0		18.0	18.0			18.0	18.0						
			19.5	20.0	19.0	19.0										19.0											
9								18.0	17.0				19.0														
				20.7	19.0	19.0	18.0	18.5				19.0	19.0														
10											19.0			18.0		17.5				18.3							
				19.0	20.0	20.0	18.8	19.0	17.5							17.0											
11									19.0			15.5	18.0		18.0	18.0											
				19.3	19.5		18.5								19.0		18.0										
12												16.0			17.0	17.3			16.3	18.5	17.0						

TABLE 24—Continued

Branches starting at top	June		July																			August					
	29	30	1	2	3	6	7	8	9	10	12	13	14	15	16	17	20	22	26	27	29	31	5	6	7	10	16
13				20.3	20.7	18.8	18.0	19.5	17.0	.....	17.0	17.5	.....	.....	.....	.....	.....	.....	.....	.....	17.0	.....	.....	.....	.....	.....	.....
											16.0	.....	17.0	19.0	18.5	17.0	16.0	.....	.....	18.0	16.5	.....	.....	19.0	.....	.....	.....
14				20.0	.....	19.5	.....	17.7	17.0	17.0	17.7	17.3	16.0	17.0	.....	18.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
											15.0	.....	17.5	18.0	.....	17.3	17.0	18.5	.....	.....	15.0	16.0	15.5	.....	16.0	.....	.....
15				19.0	20.3	19.0	.....	18.0	17.0	17.5	17.2	17.5	18.0	17.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
											19.0	.....	.....	18.5	.....	.....	18.8	17.7	.....	16.0	16.3	.....	.....	.....	.....	.....	.....
16				19.5	19.5	18.2	18.7	18.2	18.3	17.7	17.5	17.0	17.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
														19.0	.....	.....	.....	.....	.....	16.0	17.0	.....	.....	.....	.....	.....	.....
17						19.5	18.5	19.3	18.2	19.0	16.8	.....	.....	17.5	18.0	17.0	15.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
												17.0	.....	.....	.....	.....	16.0	16.0	16.0	.....	.....	16.0	.....	.....	19.0	.....	.....
18						19.5	.....	.....	18.4	18.6	17.4	16.8	20.0	15.6	17.0	17.3	.....	17.0	.....	.....	18.0	.....	.....	.....	.....	.....	.....
																	18.0	17.7	19.0	.....	.....	.....	.....	.....	19.0	16.0	.....
19							19.0	17.0	17.5	18.0	17.0	18.0	16.7	.....	.....	.....	.....	16.0	.....	.....	.....	.....	.....	.....	.....	.....	.....
											16.0	.....	.....	.....	.....	.....	.....	.....	15.5	16.7	18.0	.....	16.7	.....	.....	.....	.....
20						19.0	.....	.....	18.0	17.7	17.3	17.7	16.6	16.8	16.6	16.2	16.5	16.2	14.0	.....	.....	.....	.....	.....	.....	.....	16.0
						17.0	18.5	20.0	17.7	18.0	17.8	17.5	18.2	17.3	17.5	17.7	17.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
21																	18.0	17.5	17.7	17.0	.....	.....	.....	.....	.....	16.0	.....
						20.0	18.5	18.0	15.0	16.0	16.8	17.3	16.8	16.6	16.2	17.5	16.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
22													17.0	.....	.....	16.0	16.0	17.0	16.0	.....	17.0	14.7	.....	.....	.....	16.0	.....
						19.0	.....	19.5	.....	16.5	18.3	17.3	17.0	15.3	17.0	18.3	17.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
23														15.0	.....	17.3	16.5	.....	16.0	16.3	.....	17.5	.....	.....	.....	.....	.....
						19.0	19.0	18.0	.....	17.7	17.3	16.7	17.6	17.4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
24																			16.0	16.8	.....	17.0	16.0	.....	.....	.....	.....
						18.3	.....	.....	19.0	.....	16.5	16.3	17.2	17.1	16.5	13.0	16.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
25																											
											16.0	.....	16.5	15.5	16.3	.....	17.0	16.3	16.5	17.3	17.0	16.0	.....	.....	.....	.....	.....
No. of heads with averages	1	3	6	22	22	47	28	36	41	42	57	48	40	44	29	22	18	8	2	.....	3	.....	.....	.....	.....	.....	.....
	19.0	20.0	19.2	19.7	19.6	18.9	18.6	18.4	17.7	17.7	17.2	17.2	17.3	16.9	16.9	16.9	16.6	16.7	15.0	.....	17.7	.....	.....	.....	.....	.....	.....
						1	1	3	7	1	12	8	7	17	12	23	23	25	16	26	22	13	3	2	3	3	
						18.0	19.0	17.3	18.1	19.0	18.2	16.7	17.3	17.3	17.2	17.3	17.5	17.5	16.4	17.2	16.7	16.0	16.7	17.5	17.7	16.0	16.0

TABLE 25

SEASONAL DISTRIBUTION OF FLOWER NUMBER PER HEAD FOR FIRST YEAR OF BLOOM OF PLANT (A) AND A PLANT OF BARBE DE CAPUCIN (*E₂₂*), DAILY AVERAGES ARRANGED (Terminals, in ordinary type; laterals, in italics)

Branches starting at top	June												July		
	16	18	19	22	23	24	25	26	27	28	29	30	1	2	3
Main	17.0	17.0	17.5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
				16.5	17.0	.....	16.0	.....	16.0	.....	.....	15.0	.....	.....	16.0
1	17.0	19.0	.....	.....	16.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
									17.0	.....	.....	.....	.....	.....	.....
2	16.0	17.5	.....	.....	.....	.....	19.0	.....	.....	.....	.....	.....	.....	.....	.....
				16.0	.....	.....	17.0	.....	.....	18.0	.....	.....	.....	17.0	.....
3			17.0	17.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
					16.0	17.5	.....	17.0	.....	.....	16.0	19.0	16.0	.....	.....
4					17.0	19.0	16.0	.....	.....	.....	15.0	.....	.....	.....	.....
												17.0	16.8	.....	.....
5					17.0	.....	16.0	18.7	.....	.....	18.0	15.0	16.0	.....	.....
										17.0	.....	.....	16.0	.....	.....
6					17.0	.....	.....	19.0	20.0	17.0	.....	16.0	.....	.....	.....
									17.5	17.0	.....	16.5	16.5	15.5	16.5
7						19.0	19.0	19.0	16.0	18.0	.....	15.0	.....	16.0	.....
									17.5	.....	16.0	15.0	.....	15.0	15.0
8								17.0	16.5	.....	15.0	17.0	.....	16.0	.....
										16.0	.....	.....	16.3	15.7	15.5
9						19.0	18.0	19.0	17.0	.....	16.0	16.5	15.0	.....	15.5
										16.0	.....	15.0	.....	16.5	16.0
10								19.0	18.0	16.5	.....	16.0	16.5	16.0	.....
														15.0	16.7
11									17.0	.....	16.0	17.5	18.0	.....	17.0
												17.0	16.0	.....	16.5
12										16.0	.....	.....	.....	16.7	16.0
													16.0	.....	15.5
No. of heads with averages	4	6	3	1	6	3	5	10	7	7	6	11	5	7	6
	17.2	17.4	17.3	17.0	16.8	19.0	18.0	18.5	17.4	16.7	16.0	16.3	15.4	16.3	15.8
				4	2	2	2	1	6	6	2	8	16	10	22
				16.5	16.5	17.5	16.5	17.0	16.7	16.8	16.0	16.4	15.3	15.8	15.9

first five days of bloom; no data were obtained on the sixth and seventh days of bloom, but on each of the eighth and ninth days one head opened. From then on the number of such heads gradually but steadily increased and the number of terminal heads decreased. From July 29 to the end of blooming period (August 16) only lateral heads bloomed.

It is also plain that the average number of flowers per head for both terminals and laterals steadily decreases as the season of bloom advances, and that both the maximum and minimum numbers are lower for laterals. In respect to the total number of flower heads, only indirectly shown by averages in tables, there is

TABLE 25—Continued

AN F₃ GENERATION PLANT (*A* × *E*₂₂)-9-4- no. 14, DERIVED FROM CROSSING THE WILD ACCORDING TO POSITION OF BRANCH AND OF HEAD ON BRANCH. DATA FOR 1915.

July															August	
6	7	8	9	10	12	13	16	17	19	20	26	29	30	31	2	6
.....																
.....					14.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....																
.....																
.....	16.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....						17.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....																
.....																
.....						15.5	.....	.....	.....	.....	16.0	.....	.....	.....	.....	.....
.....																
16.7								17.0	.....	.....	.....	.....	.....	17.0	.....	.....
.....																
.....										15.5	.....	.....	.....	12.0	.....	.....
.....																
16.5	15.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	12.0	.....
.....																
.....										16.0	.....	.....	.....	.....	.....	.....
.....																
15.3			15.0	.....	15.0	16.0	.....	.....	.....	.....	.....	.....	.....	15.5	.....	.....
16.0			15.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
15.5				15.0	16.0	.....	.....	.....	14.0	.....	.....	15.0	.....	.....	.....	.....
.....															15.0	.....
15.3			19.0	15.0	.....	15.0	17.0	.....	.....	.....	.....	15.5	14.5	14.3	14.7	15.0
.....																
2			1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	.....
16.5			15.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	15.0	.....
13	6	4	3	2	3	3	1	1	1	3	3	3	2	7	5	1
15.8	14.8	15.8	16.3	15.0	15.0	15.8	17.0	17.0	14.0	15.7	16.0	15.7	14.5	14.7	14.0	15.0

also quite similar performance in that the maximum number for both terminal and laterals is about midway in the period of their appearance; the maximum for laterals therefore is on a date slightly later than the maximum for terminals.

In comparing the terminals and laterals as summarized in respect to rate of decrease (*b*) and value of first day of bloom (*a*) some differences appear. The terminals bloomed for a period of 28 days and gave a value of 19.6 for *a* and for *b* of -0.138. The laterals bloomed 41 days and for these the value of *a* is 18.0 and for *b* is -0.045. The rate of decrease in number per head for the laterals is less than that of the terminals.

The other four plants, which were studied intensively, agreed

with the behavior reported above for general performance of terminal and laterals. However, minor differences were present, so the performances of no two plants were identical in detail. This may be shown by data for one other plant as given in TABLE 25. Here the laterals came into bloom much sooner and a few terminals appeared very late in the season.

We may now consider the relative performance of different branches of a plant.

For the plant reported in TABLE 24, the first head to bloom was situated on the lateral branch that was sixth in rank from the top. On the following day a head opened on each of branches no. 4, 5, and 7; on the next day heads opened on 1, 2, 3, 8, and 9; on the following day heads bloomed on the main terminal branch and on 10-16. No data were collected on the 4th and 5th, but on the 6th, or eight days after first bloom, all the main and all the lateral branches of the plant had produced at least one flower head.

In general the performance of each branch is quite like that of the plant as a whole. Terminals come into bloom first, laterals continue to bloom later than terminals, the average flower number per head decreases as the season advances. A comparison of the performance of different branches, however, shows that the averages of the first flower heads on most branches are not decidedly different, which means that the rate of decrease in average number per head for a plant as a whole is usually less during the first part of the season while the different branches are coming into bloom than it is later when all branches have come into flower and most of the first terminals have bloomed.

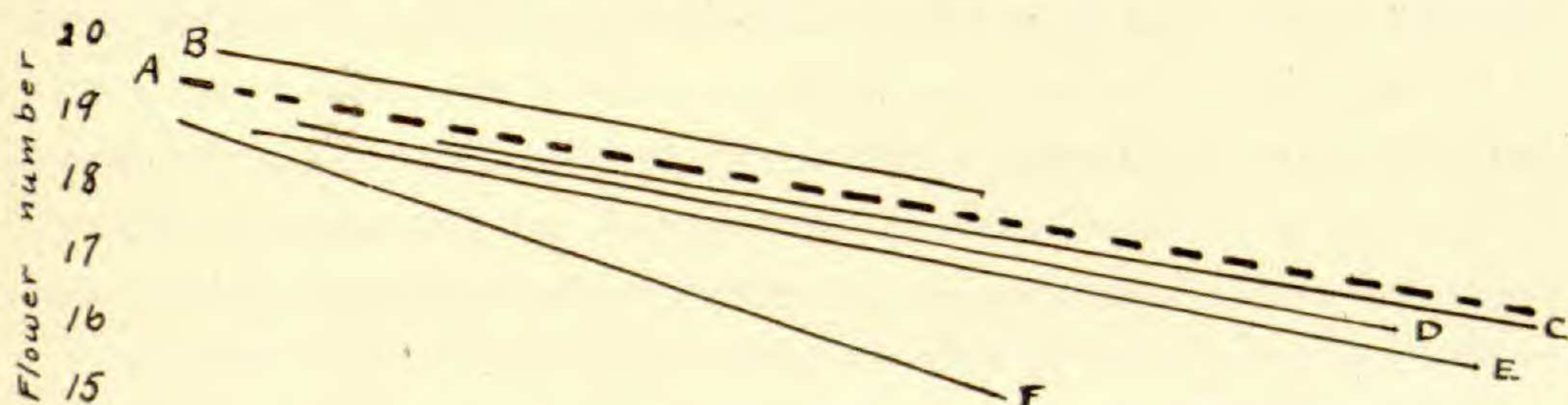
Individual differences for the various branches in the relative time of blooming are in evidence and constitute a factor contributing to the rate of decrease as determined. For the plant reported in TABLE 25 eleven days elapsed before all the main branches were in bloom. Some irregularity was also seen in that the seventh and ninth branches started bloom with higher values per head (19) than were realized in the first heads to bloom on branches 1, 2, 4, 5, and 6. Such a performance influences the actual curve of average flower number and rate of change for the plant as a whole, giving for the first few days an actual increase in the average.

The relative average performance of each branch and the

average performance of the plant as a whole are shown for each of the two plants discussed above in the diagrams of TABLES 26

TABLE 26

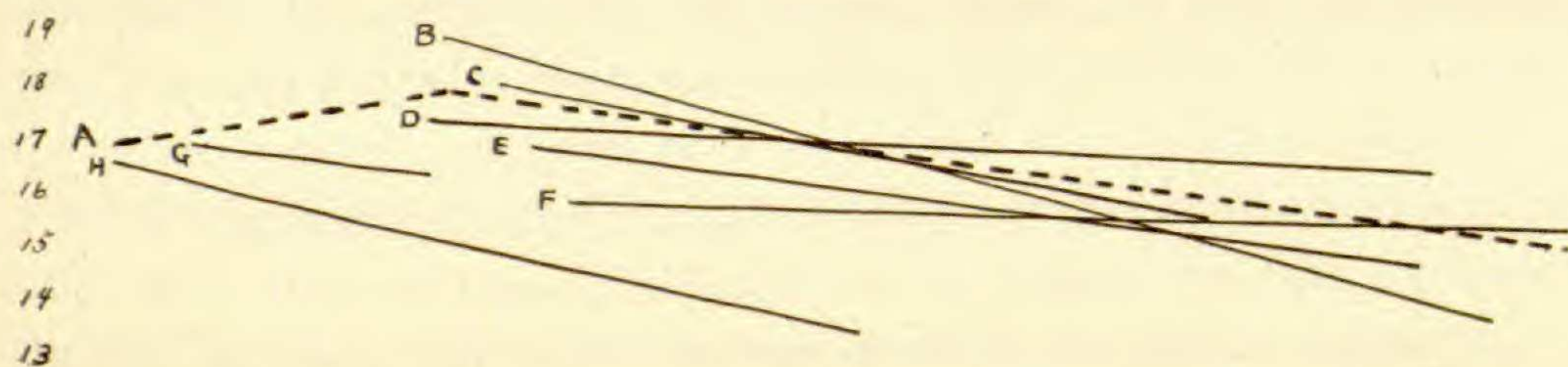
DIAGRAM SHOWING DECREASE IN FLOWER NUMBER PER HEAD FOR PLANT ($A \times E_3$) no. 4 AS A WHOLE AND FOR ITS DIFFERENT BRANCHES DURING A SINGLE SEASON OF BLOOM. DRAWN TO A SCALE WITH ORDINATES GIVING FLOWER NUMBER AND ABSCISSAS REPRESENTING PERIODS OF BLOOM



- A. Entire plant.
- B. Branches 4, 5, and 7.
- C. Branches 17 to 25.
- D. Unbranched portion of main axis and branches 10 to 16.
- E. Branches 1, 2, 3, 8, and 9.
- F. Branch 6.

TABLE 27

DIAGRAM SHOWING DECREASE IN FLOWER NUMBER PER HEAD FOR PLANT AS A WHOLE AND FOR DIFFERENT BRANCHES. FROM DATA OF PLANT ($A \times E_{22}$)-9-4-no. 14. ORDINATES ARE FLOWER NUMBER PER HEAD; ABSCISSAS REPRESENT PERIODS OF BLOOM



- A. Entire plant.
- B. Branches 7 and 9.
- C. Branches 8 and 10.
- D. Branches 4, 5, and 6.
- E. Branch 11.
- F. Branch 12.
- G. Branch 3.
- H. Unbranched part of main axis and branches 1 and 2.

and 27. To avoid the complication of many lines, branches that started to bloom on the same day were averaged as indicated.

The performances of the different branches of the plant shown in TABLES 24 and 26 were more similar than those of the different branches of the plant reported in TABLES 25 and 27. The graphs in the latter case overlap and cross and the graph for the plant as a whole is less in agreement with that of a single branch.

From such studies of the individual behavior of the different branches we gain some clue to the immediate causes of the irregularities which appear in the data collected from day to day, and of the irregularities that appear in the rate of decrease in the number of flowers per head. Differences in the relative development of the various branches, and the number of branches produced, have a marked influence on the average flower number observed from day to day and in the corresponding rate of decrease.

It is apparent that the irregularities are due chiefly to variations in behavior of the different branches during the first twenty or twenty-five days of blooming and are chiefly due to the number of branches and to the rate with which these come into bloom. The averages for the whole plant may show no decrease, a very slight decrease, or even a slight increase (see TABLE 27) during the period of first blooming, due to the fact that day after day for a longer or shorter time new branches begin to bloom all with a high flower number per head. If, however, a considerable number of branches have been in bloom for some time and are showing a marked decrease in flower number per head when late branches come into bloom, the higher flower numbers of the latter will for a time retard the rate of decrease. The irregularities occur chiefly at the beginning and the end of the period of blooming. In all cases the rate of decrease is less until all branches are in bloom.

It would appear that the most typical development of a plant is such that the branches from the oldest to the youngest show characteristic differences in the number of flowers per head and in the rate of decrease, which may be somewhat analogous to the behavior of a plant at different ages. The uppermost branches in comparison with the lower branches of the same plant are, as a rule, smaller, have fewer heads, bloom for a shorter period, and show less decrease in flower number. While the variations in and among the various branches of different plants considered as wholes are so pronounced that a perfect or exact type of develop-

ment of this sort is not realized, the strong tendency to such a type is more or less evident from the data which show that there is a decrease for branches according to the relative time of blooming, which merges into and contributes to the general decrease of the flower number for the plant as a whole.

The more absolute calculation of the decrease of average number per head, therefore, involves the factor of position of the various branches involving their age, length of life, and number. This decrease, due to position, may be considered as an unknown c and its value calculated in the same manner as that of b . If n be used to represent the number of the branch, we may introduce these two new factors into the equation which now becomes $o = a + bt + cn$. Three simultaneous equations can be developed by the same methods already used, giving

$$(1) [o] = a + b[t] + c[n]$$

$$(2) [ot] = a[t] + b[t^2] + c[tn]$$

$$(3) [on] = a[n] + b[tn] + c[n^2]$$

In order that the rate of decrease for each branch be given its full weight, uninfluenced by the high flower number of the branches that begin to bloom later, the data were so arranged that the same starting point was taken for all branches; that is, all the observations for first day of bloom, second day of bloom, etc. were grouped together, regardless of dates. From TABLE 28 the values of a , b , and c for the plant ($A \times E_3$) no. 4 were calculated. In order to simplify the calculations the observations are put down as $+$ and $-$ deviations from 18.0.

Comparisons show that both series of calculated values correspond fairly well with the observed values. It does not, of course, appear from the data on this one plant that the values computed when both time and position are taken into account are in better agreement with the observed values than if time alone be considered. In order that the reader may judge of the amount of agreement, there is presented for comparison in TABLE 29 (1) the flower numbers actually observed on various dates after the first day of bloom without taking position into account, (2) the theoretical values for the same dates with regard to the factor of time, and (3) the values when both time and position are taken into account.

TABLE 28

TABLE FOR CALCULATION OF VALUE OF FIRST DAY OF BLOOM (*a*), WHERE POSITION OF HEAD UPON WHICH DATA OF SEASONAL DISTRIBUTION

Branches, starting from top	Days															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Main	1.0	0.2	.....	.....	0.0	.....	.....	- 1.0	1.0	.....	1.5	- 1.0	1.0	1.0	.....	0.5
1	1.0	.....	.....	.....	.....	.....	1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	1.0	.....	.....	.....	.....	2.0	.....	.....	.....	.....	.....	.....	.....	.....	1.0	1.0
3	1.0	.....	.....	1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
4	2.0	.....	.....	.....	.....	.....	0.5	.....	.....	.....	.....	.....	0.0	.....	.....	.....
5	2.0	.....	.....	1.0	.....	.....	.....	.....	.....	.....	.....	.....	0.0	.....	.....	.....
6	1.0	.....	.....	.....	1.0	.....	.....	.....	.....	.....	.....	2.0	.....	.....	.....	.....
7	2.0	.....	-1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.0	.....	.....	.....
8	1.0	1.0	2.0	.....	.....	.....	1.3	2.0	.....	.....	.....	1.0	1.0	.....	1.0	.....
9	1.5	2.0	1.0	.....	.....	1.0	.....	0.0	-1.0	.....	.....	.....	.....	1.0	.....	.....
10	2.7	1.0	.....	.....	1.0	0.0	0.5	.....	.....	.....	1.0	1.0	1.0	0.0	.....	-0.5
11	1.0	2.0	.....	.....	2.0	0.8	1.0	0.0	.....	.....	.....	- 2.5	.....	0.0	0.0	-0.5
12	1.3	1.5	.....	.....	.....	0.5	.....	.....	.....	.....	.....	- 2.0	.....	.....	0.0	-0.7
13	2.3	2.7	.....	.....	0.8	0.0	.....	- 1.0	.....	.....	-1.5	- 0.5	-1.0	1.0	0.5	-1.0
14	2.0	.....	.....	.....	1.5	.....	-0.3	- 1.0	.....	.....	-0.4	- 0.5	-2.0	-0.7	-1.0	0.3
15	1.0	2.3	.....	.....	1.0	.....	0.0	- 1.0	-0.5	.....	-0.4	- 0.5	0.0	0.0	.....	.....
16	1.5	1.5	.....	.....	0.2	0.7	0.2	0.3	-0.3	.....	-0.5	- 1.0	-1.0	1.0	.....	.....
17	1.5	0.5	1.3	0.2	1.0	.....	-1.2	- 1.0	-0.5	0.0	-1.0	- 2.7	.....	.....	-2.0	.....
18	1.5	.....	0.4	0.6	-0.1	.....	-0.6	- 1.2	2.0	-2.4	-1.0	- 0.7	.....	.....	0.0	.....
19	1.0	-1.0	-0.5	0.0	.....	-1.2	0.0	- 1.3	.....	.....	.....	.....	.....	.....	.....	.....
20	1.0	.....	.....	0.0	-0.3	.....	-0.7	- 0.3	-1.4	-1.5	-1.3	- 1.9	.....	.....	-1.0	.....
21	-1.0	0.5	2.0	-0.3	0.0	.....	-0.2	- 0.5	0.2	-0.7	-0.5	- 0.2	.....	.....	-0.7	.....
22	2.0	0.5	.....	0.0	-3.0	-2.0	-1.2	- 0.7	-1.2	-1.4	-1.8	- 1.0	.....	.....	.....	.....
23	1.0	.....	1.5	-1.5	.....	0.3	-0.7	- 1.0	.....	-2.8	-1.0	- 0.5	.....	.....	-1.2	.....
24	1.0	1.0	0.0	.....	-0.3	.....	-0.7	- 1.3	-0.4	-0.6	.....	.....	.....	.....	.....	.....
25	0.3	.....	.....	1.0	-0.8	.....	-1.6	- 1.7	-1.0	-1.5	-1.7	- 5.0	.....	.....	-1.5	.....
Totals...	33.6	15.7	6.7	2.0	4.0	2.1	-2.7	-11.7	-3.1	-9.6	-8.6	-16.0	-1.0	3.3	-4.9	-0.9

$$[o] = -0.2 \quad [t^2] = 187.79$$

$$[ot] = -8.3 \quad [n] = 14.9$$

$$[on] = -7.1 \quad [n^2] = 268.49$$

$$[t] = 10.8 \quad [tn] = 160.37$$

The collection of data and the calculations which take the rate of decrease of the various branches into account, while simple, are extremely laborious and consume much time. The collection of such extensive data for a very large number of plants is scarcely possible. Such data are desirable in the analysis of the sources of the variability and may indicate the proper methods of obtaining from a larger number of plants the data that will admit of more general analysis and comparison.

The question naturally arises whether in a plant with a long blooming-period such as chicory the random collection of data at intervals of every third day throughout the flowering period will

TABLE 28—Continued

PLANT IS TAKEN INTO CONSIDERATION. DATA FOR THE F_1 GENERATION PLANT ($A \times E_3$) no. 4, FOR TION ARE PRESENTED IN TABLE 24

Days																Totals
16	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	
.....	1.0	.....	.....	.....	.....	.....	.....	- 0.5	.....	0.0	.....	.....	.....	.....	.....	3.7
.....				1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	-3.0	0.0
.....													-3.0	.....	.....	2.0
.....																2.0
.....																2.5
.....																3.0
.....								- 3.0	.....	.....	.....	.....	.....	.....	.....	1.0
.....					-2.0	.....	.....	.....	.....	.....	.....	-1.0	.....	.....	.....	- 0.7
0.0		0.0	.....	.....	.....	.....	.....	.....	0.0	.....	0.0	.....	.....	.....	.....	10.3
1.0										0.3	.....	.....	.....	.....	.....	6.8
.....								0.3	.....	.....	.....	.....	.....	.....	.....	8.0
.....																3.8
.....	0.0	.....	.....	.....	.....	.....	-1.7	0.5	.....	-1.0	.....	.....	.....	.....	.....	- 1.6
.....	-2.0	.....	-1.3	.....	.....	.....	.....	0.7	.....	.....	.....	.....	.....	.....	.....	- 0.3
.....							-3.0	- 2.0	.....	-2.5	.....	.....	.....	-2.0	.....	-11.6
.....	0.8	.....	-0.3	.....	.....	.....	.....	- 2.0	.....	-1.7	.....	.....	.....	.....	.....	- 1.3
.....							-2.0	.....	.....	-1.0	.....	.....	.....	.....	.....	- 0.4
-2.0						0.0	.....	- 2.0	.....	.....	1.0	.....	.....	.....	.....	- 7.9
-1.7			1.0	.....	.....	.....	.....	.....	.....	.....	1.0	-2.0	.....	.....	.....	- 3.2
.....		-2.3	-1.3	.....	.....	.....	0.0	- 1.3	.....	.....	.....	.....	.....	.....	.....	- 7.9
-1.3			-2.0	.....	.....	-1.7	.....	- 2.0	.....	.....	.....	.....	-2.0	.....	.....	-16.4
-0.3			-1.0	.....	.....	.....	.....	.....	.....	.....	.....	-2.0	.....	.....	.....	- 4.7
-1.0			-2.0	.....	.....	-1.0	.....	- 3.3	.....	.....	.....	.....	.....	.....	.....	-17.1
.....			-2.0	-1.7	.....	.....	.....	- 0.5	.....	.....	.....	.....	.....	.....	.....	- 9.1
.....			-2.0	-1.2	.....	.....	.....	- 2.0	.....	.....	.....	.....	.....	.....	.....	- 7.5
.....			-1.5	-0.7	.....	.....	.....	- 2.0	.....	.....	.....	.....	.....	.....	.....	-18.7
-5.3	-0.2	-2.3	-12.4	-2.6	-2.0	-4.7	-6.7	-19.1	0.0	-5.9	2.0	-5.0	-5.0	-2.0	-3.0	.....

$$1 \quad -0.2 = a + 10.8b + 14.9c$$

$$2 \quad -8.3 = 10.8a + 187.79b + 160.37c$$

$$3 \quad -7.1 = 14.9a + 160.37b + 268.49c$$

$$\text{Solving, } b = -0.086$$

$$c = -0.095$$

$$a = +2.2 (20.2)$$

adequately represent the variations in flower number per head and give data for a rate of decrease for the plant as a whole which adequately considers the variation due to position. Some evidence on this point is to be had from the relative dates upon which branches with the same relative position come into bloom on dif-

TABLE 29

OBSERVED AND THEORETICAL VALUES OF FLOWER NUMBER PER HEAD FOR AN F_1 GENERATION PLANT ($A \times E_3$) no. 4, FROM DATA GIVEN IN TABLES 24 AND 28

Days of bloom.....	0	4	14	18	29
Observed values.....	19.0	19.6	17.8	17.2	16.8
Values computed for time ($a - 0.066t$).....	18.9	18.6	18.0	17.7	17.0
Values computed for time and position ($a - 0.086t - 0.095n$).....	19.0	18.4	17.5	17.6	16.2

ferent plants. Such data for the main and for the successive fifteen branches of seven plants are presented in TABLE 30. For each plant the date of first blooming of any branch is considered as zero and all later blooming calculated from this. Observations are not complete for all branches, as indicated by the dashes.

TABLE 30
RELATIVE DAY OF FIRST BLOOM FOR MAIN STEM AND 15 BRANCHES NUMBERED FROM TOP DOWN, FOR SEVEN PLANTS

Plants	1	2	3	4	5	6	7	
Branches, starting from above	Day of first bloom							Average
Main	0	1	—	4	0	6	5	2.7
1	0	—	0	3	0	3	11	2.8
2	0	1	—	3	0	2	6	2.0
3	1	1	2	5	2	2	5	2.6
4	1	1	2	1	5	1	5	2.3
5	1	0	2	1	5	1	4	2.0
6	1	0	—	0	5	0	4	1.7
7	—	2	—	1	6	1	3	2.6
8	1	4	4	3	8	1	2	3.3
9	1	4	4	3	6	6	1	3.7
10	1	5	4	4	8	6	0	4.0
11	3	4	2	4	9	8	0	4.3
12	3	5	—	4	10	10	0	5.3
13	3	5	4	4	—	—	3	3.8
14	3	5	4	4	—	—	5	4.2
15	3	—	4	4	—	—	8	4.8
None lower observed								

While the number of plants observed is not large, it is sufficient to show variations in the type of development and illustrates the fact that there is considerable variation in the position of the branch that first comes into bloom and likewise in the relative time in which branches similarly placed come into bloom. While it is generally one of the uppermost branches that blooms first, the general development of a plant with respect to size, number of branches, etc., may be such that, as seen in plant no. 7 of TABLE 30, the 10th, 11th and 12th branches from the top may bloom first. The largest variability for branches of any one position is eleven days, seen in the first from the top, and the least is two days, exhibited by branches 13 and 14.

In spite of these irregularities, it appears that for the average relative date of bloom for the different branches of individual plants there is little individual variability and that one may secure

quite adequate data by making collections from the plant as a whole, especially when the data are well distributed over the season and form a rather large total.

C. The phenomenon of intermittent annual growth.

Opportunity for further study of the influence of position and time of development on the number of flowers per head was given by a very marked variation of vegetative habit, giving discontinuous development or two periods of growth in a single year.



TEXT-FIGURE 1. Two plants of the race (race 3) exhibiting intermittent growth. Photo taken late in autumn.

To left a plant with first growth cut away, leaving only second growth.

To right a plant showing both first and second growth. The first growth was about twice as tall as the second and when photographed was dead and dry while the second growth was green and flowering profusely.

As a rule the seasonal development of the various branches is so continuous and overlapping that there is a sequence of bloom and no interruption in the blooming of a plant as a whole. The last to develop of the main laterals are the most basal of the laterals and are from the uppermost of the rosette leaves.

TABLE 31

SEASONAL DISTRIBUTION OF FLOWER NUMBER PER HEAD FOR A ONE-YEAR-OLD PLANT OF AN
PLANT (A) AND A PLANT OF BARBE DE CAPUCIN (E_{22}).

Number of flowers per head	August											September				
	2	5	8	10	12	15	17	21	24	26	29	1	5	7	11	13
13	.....	.....	I	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
14	.....	.....	I	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
15	I	I	I	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
16	3	3	2	4	4	4	.....	2	.....	.....	.....	I	.....	.....	.....	.....
17	.....	4	2	3	4	2	.....	.....	I	.....	.....	I	2	.....	I	2
18	.....	I	.....	I	I	2	2	4	6	3	3	6	3	7	4	.....
19	.....	I	.....	.....	.....	.....	.....	I	.....	3	I	I	3	3	I	.....
Averages...	17.6	17.2	16.6	16.6	16.7	16.3	.....	16.7	17.0	.....	.....	16.0	.....	.....	.....	.....
	.....	.....	16.3	16.5	16.0	16.5	16.4	16.7	16.7	17.2	16.8	16.8	17.3	17.3	16.7	16.0

$$\begin{aligned}
 \text{Old growth } [o] &= 16.7 & a &= 16.9 \\
 [ot] &= +2.79 & b &= +0.009 \\
 [t] &= 26 & t &= 54 \\
 [t^2] &= 271.55
 \end{aligned}$$

In one line of descent there was a marked deviation from this habit of seasonal growth which was very striking in that an entire series of sister plants in 1916 exhibited this deviation. After the branches that usually develop were through blooming, young and new branches appeared from the axils of many of the rosette leaves (which had died); these continued to grow, making a bushy compact second growth quite distinct from the earlier growth both as to time of development and to position on the plant. This habit of growth is shown in TEXT-FIGURE 1. To the right is a plant with the growth of both periods shown; the older dead branches of the first period extend above the newer growth. To the left the old growth has been cut away, leaving only the branches of the second period. Between the close of the blooming of the first growth and the beginning of bloom on the second growth there was usually an interval of several days.

Complete data collected for the flower heads of two periods of growth for a single plant $\{(A \times E_{22}) - 9-5-12 - no. 6\}$ are pre-

TABLE 31—Continued

F₄ GENERATION (*A* × *E*₂₂)—9-5-12— no. 6, DERIVED FROM A CROSS BETWEEN THE WILD DATA FOR 1916. Terminals, in ordinary type; laterals, in italics)

September				October									November				
16	19	22	25	5-7	9-10	10-13	14-16	17-20	21-23	24-26	27-30	31-2	4-6	8-9	11-14	16	
.....									I		I						Death
.....																	
.....	.....	.....	.....	2	.....	3	2	I	5	2	4	4	I	.....	.....	.....	
.....	<i>I</i>	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
.....	.....	.....	.....	3	2	2	7	9	2	7	I	2	2	3	2	.....	
.....	<i>I</i>	.....	.....	.....	.....	.....	.....	.....	2	.....	.....	<i>I</i>	2	.....	.....	<i>I</i>	
.....	.....	.....	.....	I	I	I	I	.....	.....	2	.....	.....	I	.....	.....	.....	
<i>I</i>	<i>I</i>	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3	<i>I</i>	.....	.....	
.....	.....	.....	.....	.....	.....	.....	.....	I	.....	.....	.....	I	.....	I	.....	.....	
6	.....	<i>I</i>	<i>I</i>	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
.....											I						
<i>I</i>	<i>I</i>	<i>I</i>	.....	.....	.....	.....	.....	.....	.....	.....	<i>I</i>	.....	.....	.....	<i>I</i>	.....	
.....																	
.....	<i>I</i>																
.....				14.8	15.3	14.8	14.9	16.1	14.1	15.0	14.0	14.7	15.0	15.6	15.0		
17.0	16.4	17.5	17.0						15.0			16.0	15.6	16.0	17.0	15.0	

New growth [o] = 14.9

[ol] = + 1.64

[l] = 19

[l²] = 142.83

a = 15.1

b = + 0.011

t = 42

sented in TABLE 31. The growth of the first period ended bloom on the 25th of September. The data collected for this period showed that the averages from day to day throughout indicate an increase in flower number per head (*b* = +0.009).

The new growth began bloom on the 5th of October and had only partly completed bloom when it was killed by frost. The data for the new growth are necessarily incomplete and mostly from terminal heads. Data were collected from the new growth every day, but to avoid extending the tables the data are summarized for every consecutive three days of collection; the totals for each column are therefore larger than when a column gives only data obtained in a single day. What was collected showed that there was here also an increase of number per head (*b* = +0.011).

The performances of the two periods were similar in yielding a slight increase in number per head. The average number per head and the value for the first date of bloom for the two were much higher for the first period. The lower branches which formed

TABLE 32

SEASONAL DISTRIBUTION OF NUMBER OF FLOWERS PER HEAD FOR A ONE-YEAR-OLD PLANT OF AN PLANT (A) AND A PLANT OF BARBE DE CAPUCIN (E₂₂). DATA FOR

Number of flowers per head	July	August										September					
	31	3	7	9	12	15	18	21	24	26	30	1	6	8	11	13	16
11	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	I
12	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	I
13	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	I	.....	I	I
14	.....	.....	I	.....	.....	.....	.....	.....	.....	.....	I	.....	.....	3	I	.....	I
15	I	.....	.....	I	I	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
16	I	I	6	5	I	I	.....	2	I	.....	I	I	2	I	3	3	4
17	.....	.....	.....	.....	2	5	2	.....	2	2	3	6	4	2	3	2	I
18	.....	3	2	.....	I	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
19	.....	.....	I	2	3	3	3	7	4	5	2	3	3	2	2	3	I
20	.....	3	.....	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Averages	15.5	17.9	16.0	16.4	16.0	.....	16.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	.....	.....	17.0	17.0	16.6	16.2	17.2	16.7	17.2	17.0	16.3	16.2	16.1	15.4	15.9	15.9	14.3

Old growth [o] = 16.1

a = 17.0

[ot] = - 7.90

b = - 0.032

[l] = 29

t = 57

[l²] = 246.40

the growth of the second period started in with lower average numbers per head.

Most plants of this race exhibited a minus value for rate of change (an actual decrease): the typical performance being as shown in TABLE 32. For this plant the growths of the two periods both show a rate of decrease. The values of *a* and [o] for the new growth are decidedly lower than those of the old growth.

4. INDIVIDUAL VARIATIONS FROM THE USUAL PERFORMANCES AS TO SEASONAL DECREASE

Marked deviations from the usual behavior of seasonal decrease have been found. Data for two such cases have already been given in TABLES 3 and 4.

In the course of the studies a few plants were found which in the performance for a season exhibited an actual increase of average flower number per head. This is quite the reverse of the usual performance. Data for one of the most marked cases of such increase are given in the following table (TABLE 33). This plant was one of the F_4 generation grown in 1916 and the data as collected distinguished between terminals and laterals for the different clusters. The average or mean number for all flower heads is 17 and the value for the first date of bloom (a) is 16.4. Neither of these is an especially low value. It should be noted that this plant was one of a series of sister plants which were quite uniformly sparsely branched and had few solitary terminal heads: the heads were in clusters, quite as shown in *C* and *D* of PLATE 13. Such clusters evidently represent a shortened and compacted system involving terminals of different relative ranks with their respective laterals. The group is so compact that only the first head to bloom can be definitely regarded as terminal. If the group had not been compacted (but expanded as in *A* and *B* of PLATE 13), many of these heads would have been terminal for their respective clusters. The prevailing high numbers in the so-called lateral heads of these groups as seen in TABLE 33 may indicate that in these compacted groups of heads the laterals of lower ranks are crowded out and fail to develop as they may when the branching is more profuse. However, it must be recognized that many plants with the grouped-head habit, quite identical with the one under consideration, showed the seasonal decrease most characteristic of the species.

5. VARIATION IN PARTIAL VARIABILITY WITH THE AGE OF A PLANT

The data collected from plants in successive years of growth may now be presented with respect to the very important question of variation in seasonal performance of a plant from year to year. In the case of all perennials and especially of herbaceous perennials this point needs careful analysis before adequate comparisons between individuals can be made. All of the plants studied, with the exception of the variety red-leaved Treviso, grew as perennials, and although plants of each series winter-killed, the roots and basal portions of such plants were apparently fully alive at the end

TABLE 33

SEASONAL DISTRIBUTION OF FLOWER NUMBER PER HEAD FOR A ONE-YEAR-OLD PLANT OF AN F₄ GENERATION (A × E₂₂)—9-5-12—no. 16, DERIVED FROM A CROSS BETWEEN THE WILD PLANT (A) AND A PLANT OF BARBE DE CAPUCIN (E₂₂). DATA FOR 1916. (Terminals, in ordinary type; laterals, in italics)

Number of flowers per head	July	August										September										October				Total
	31	3	7	9	12	15	18	21	24	26	29	1	5	7	11	13	16	19	22	25	2	4	10	16		
14	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2	
	.....	.....	1	2	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	4	
15	.....	.....	.....	.....	.....	.....	.....	1	.....	2	.....	1	.....	2	1	.....	.....	.....	1	.....	.....	.....	.....	.....	8	
	1	.....	6	3	3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	13	
16	.....	.....	.....	1	.....	3	3	4	3	3	4	3	2	2	1	.....	4	1	2	.....	.....	1	.....	.....	37	
	1	4	3	1	2	1	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	13	
17	.....	.....	.....	2	3	2	5	1	2	2	4	5	7	2	6	1	5	.....	3	.....	.....	.....	1	1	52	
	1	2	.....	1	1	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3	.....	.....	.....	.....	.....	6	
18	.....	.....	.....	.....	.....	2	1	3	4	2	2	1	1	2	2	1	.....	1	3	1	.....	.....	1	.....	27	
	.....	4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	4	
19	.....	.....	.....	.....	1	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	1	1	1	.....	1	2	.....	.....	8	
																										
Averages	17.0	18.0	16.2	16.1	16.7	17.5	15.0	.....	17.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	40	
	.....	.....	.....	16.7	17.5	16.8	16.8	16.9	17.1	16.3	16.8	16.6	16.9	16.0	16.9	17.5	16.8	17.7	17.1	18.0	19.0	18.0	17.5	17.0	134	

[o] = 17.0

[ol] = + 9.94

[l] = 33

[l²] = 435.79

a = 16.4

b = + 0.018

t = 77

of the previous season of growth. The plants of the red-leaved Treviso variety died at the end of the first season of bloom.

A perennial plant of chicory grown from seed exhibits considerable interannual variation in habit of growth, especially in the first and second years of growth and bloom. In the first year of bloom a single main erect stalk usually develops from the rosette; in the second year, usually, several main stalks are produced directly from the extreme basal and lower parts of the crown, or even from clusters of roots that may or may not have become separated by the death of the basal portions of the stem of the previous year. In a few years the cluster of roots is more or less increased in size and number and the group of main branches is correspondingly increased and more or less crowded together. The degree of such development varies considerably. The wild white-flowered plant *A* showed rather feeble increase or spread of this sort; the wild white-flowered plant *C* was somewhat more vigorous in its vegetative development; and plants of the Barbe de Capucin (*E* series) were most vigorous in this respect, so that from E_3 and E_{22} in the third year of growth a large number (15 or 20) of stems arose from the roots, and as some of these developed from small detached roots they were weak and late in developing. The crowding of such a number of stems also caused the poor development of many of them. For the perennial plants upon which data were collected, it has been the policy to allow no more than three or four main branches to develop. These were selected from the first shoots and were as nearly uniform in development as possible; all other weaker or later branches from the root cluster were cut away.

It has already been reported that in the second year of growth from seed, plants are taller and more branched and have a much longer flowering period with the production of many more flowers. These differences in general habit of growth are represented by such differences in data as appear between TABLES 8 and 9 for example. These differences raise the question whether such values as those calculated for the first day of bloom (*a*) and for the rate of decrease (*b*) are consistent for a plant in the successive years of its growth from seed.

Some judgment of this question may be gained by the correla-

tion of data for those plants from which data were collected in different years. The following tables (34, 35, and 36) present such data, in values of a , which are grouped solely according to the age of the plants.

TABLE 34

CORRELATION BETWEEN FLOWER NUMBER FOR FIRST DAY OF BLOOM (a) OF ONE-YEAR-OLD AND THAT OF TWO-YEAR-OLD PLANTS

		Flower number of 2-year-old-plants										
		16	17	18	19	20	21	22	23	24	Averages	
Flower number of 1- year-old plants	16			1	1						18.5	
	17		1	7	3	3					18.6	
	18			3	3	6					19.3	
	19					4	2	1			20.6	
	20			1	1	2	1				19.6	
	21				1	1		1			20.3	
	22										—	
	23									1	24.0	
	24										—	

$r = + 0.68$

TABLE 35

CORRELATION BETWEEN FLOWER NUMBER FOR FIRST DAY OF BLOOM (a) OF THREE-YEAR-OLD PLANTS AND THAT OF ONE-YEAR-OLD PLANTS

		Flower number of 3- year-old plants							
		16	17	18	19	20	21	22	Averages
Flower number of 1-year-old plants	16	1		1					17.0
	17			1	5				18.8
	18				4		2		19.7
	19				2	6			19.8
	20					1	1		20.5
	21					1		1	21.0
	22								—

$r = + 0.68$

TABLE 36

CORRELATION BETWEEN FLOWER NUMBER FOR FIRST DAY OF BLOOM OF TWO-YEAR-OLD AND THAT OF THREE-YEAR-OLD PLANTS

		Flower number of 3-year-old plants					Averages
		18	19	20	21	22	
Flower number of 2-year-old plants	18	2					18.0
	19	1	2	6	2	1	19.0
	20		10	2	3		19.5
	21		3	9	3	1	20.1
	22		1	2	1	1	20.4

$r = + 0.60$

TABLE 34 presents the correlation of data for first and second year of blooming for 44 plants; the coefficient of correlation is $+0.68$. TABLE 35, involving 26 plants in the first and third years of growth, shows a coefficient of correlation of $+0.68$. The values of a from 50 two- and three-year-old plants show a coefficient of correlation of $+0.60$ (TABLE 36).

The values for the coefficient of correlation are remarkably uniform, which may be considered as more significant than the particular value. The correlation is also high, which, with the distribution in the tables, indicates very clearly that plants which exhibit a high value for a one year will also give high values in the following years. The value for a is strongly individual and tends to remain quite constant from year to year in spite of such differences as exist in the growth of plants in successive years. At least such is the case when the data used in the calculations are collected as described from plants grown as the chicory plants have been.

It should be pointed out that the plants utilized in this computation belong to a small number of lines of descent and that they are for the most part F_1 , F_2 , and F_3 progeny of crosses involving the wild white-flowered plants (A and C), and those of the cultivated variety (E_3 and E_{22}). The parents were widely different in general habit and the F_1 and F_2 generations likewise exhibited wide variations in such characteristics as height, vigor, general habit of branching, and period of blooming. The population as grouped in TABLES 34–36 is composed of five lines of descent. If these lines of descent showed great differences in flower number, the correlation from year to year would appear greater than it really is. From TABLE 37, however, it is evident that for plants of the same age the distribution of flower number in the different lines is essentially the same. In this table the frequencies of occurrence of flower number are recorded for each line separately. The interval used in grouping the flower number is 0.3; that is, the group 16.0–.2 includes 16.0, 16.1, and 16.2.

TABLE 37 shows data for different lines of plants in the first, second, and third years of growth. It will be seen that all the lines overlap. The series $(E_3 \times A) - 4 -$, an F_2 generation, is the only one that shows in the first and second year one plant with

a very high value for a . The other plants of this series, however, show a range of variability similar to that of the other series. In the third year one plant of the series ($E_3 \times C$) had a very low number of flowers per head, but the rest of the series agrees with the general distribution of the other series.

TABLE 37

DISTRIBUTION OF FLOWER NUMBER PER HEAD (a) FOR ONE-YEAR, TWO-YEAR, AND THREE-YEAR-OLD PLANTS OF DIFFERENT LINES

Flower number	One year old										Two years old										Three years old										
	$A \times C$	$A \times E_3$	$E_3 \times A$	$(E_3 \times A)^{-4}$	$A \times E_{22}$	$(A \times E_{22})^{-4}$	$E_{22} \times A$	$(E_{22} \times A)^{-10}$	$C \times E_3$	$E_3 \times C$	$C \times E_{22}$	$A \times C$	$A \times E_3$	$E_3 \times A$	$(E_3 \times A)^{-4}$	$A \times E_{22}$	$(A \times E_{22})^{-4}$	$E_{22} \times A$	$(E_{22} \times A)^{-10}$	$C \times E_3$	$E_3 \times C$	$C \times E_{22}$	$A \times C$	$A \times E_3$	$E_3 \times A$	$A \times E_{22}$	$E_{22} \times A$	$C \times E_3$	$E_3 \times C$	$C \times E_{22}$	
16.0-.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.3-.5	.	I	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
.6-.8	.	.	.	.	.	.	.	.	.	I	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	.	
.9-.1	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
17.2-.4	.	.	I	.	I	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
.5-.7	.	.	.	.	.	.	.	3	.	I	.	.	.	.	.	.	.	.	I	.	.	.	.	.	.	.	.	.	.	.	
.8-.0	2	.	.	.	.	.	I	2	.	.	.	.	.	.	I	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
18.1-.3	.	I	I	.	.	.	.	.	.	.	.	.	.	.	I	.	.	.	2	.	.	.	.	I	.	.	.	.	.	.	
.4-.6	I	.	I	3	.	.	I	.	.	I	.	.	I	.	.	.	.	.	3	.	.	.	.	.	I	.	.	I	.	.	
.7-.9	.	I	I	.	.	.	.	.	I	.	I	.	.	I	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
19.0-.2	.	.	I	.	.	.	.	.	.	I	.	.	I	.	.	.	.	.	I	.	.	I	.	.	.	I	2	.	I	.	
.3-.5	.	.	I	.	I	.	.	.	.	I	.	.	.	I	.	.	.	.	I	I	.	I	.	I	3	3	I	2	I	2	
.6-.8	.	.	.	I	.	.	.	.	I	.	I	I	I	.	.	I	3	.	.	.	.	.	I	I	I	.	I	I	.	.	
.9-.1	.	.	.	.	I	.	I	.	.	I	.	.	I	I	2	.	.	.	.	I	.	I	I	I	3	2	.	.	I	.	
20.2-.4	.	.	.	.	.	I	.	.	.	.	2	.	2	I	I	.	.	.	I	.	I	2	.	.	.	I	.	I	.	.	
.5-.7	.	.	.	I	.	.	.	.	.	I	.	I	2	.	2	.	I	.	I	2	.	.	.	.	I	.	.	I	I	.	
.8-.0	.	.	I	.	2	I	.	.	.	.	.	.	I	.	.	.	.	3	2	.	.	.	.	.	.	2	.	I	.	3	
21.1-.3	.	.	.	.	.	.	.	.	.	.	I	.	.	I	I	.	.	.	.	I	.	I	2	.	.	.	.	I	.	I	
.4-.6	.	.	.	.	I	.	.	.	.	.	.	.	I	.	.	.	.	.	.	.	.	3	.	.	.	.	I	I	.	.	
.7-.9	.	.	.	.	.	.	.	.	.	.	.	I	.	.	2	.	.	.	.	I	.	I	.	.	.	.	.	.	.	I	
22.0-.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	.	.	.	.	.	.	.	.	.	.	.	I	I	.	.	
.3-.5	.	.	.	.	.	.	.	.	.	.	.	.	I	I	.	.	.	.	.	I	.	.	.	.	.	.	.	.	.	.	
.6-.8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	.	.	.	.	.	.	.	.	.	.	.	.	
.9-.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
23.2-.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
.5-.7	.	.	.	I	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
.8-.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
24.1-.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	

It is quite evident then from this table that the differences in the distribution of flower number between the different series are not great enough to influence the coefficient of correlation for plants of different ages.

The plants A and C were at least in the third year of growth in 1913 when they were first used for data here reported. The

general habit of growth of each was quite uniform in 1913, 1914, and 1915. The parents E_3 and E_{22} were in their second year of growth in 1913. During the winter of 1914-1915, the plant E_{22} was destroyed by pine mice. In the early spring of 1915 the roots of each plant (A , C , and E_3) were divided in two and grown as two plants, from which data were taken separately. The data for these various plants and for the hybrid generations are tabulated in TABLES 38 and 39.

It is clear from these comparisons that there is a rather close agreement in the behavior of a plant in successive years with respect to the production of flower number as determined by the calculated values for a . The nature of the development of a plant and the many factors contributing to fluctuations in development and production of flower number are such that exact agreement is not to be expected. The variations in the value of a for any one plant from year to year follow a rather uniform course. The value is, as a rule, lower for the first year of bloom than for the second and there is a further slight increase in the third year. The behavior of a plant is more uniform in the second and third years of growth. The data for plants A , C , E_3 , and E_{22} indicate that such is also the case in later years.

TABLE 38

FLOWER NUMBER PER HEAD (a) IN THREE SUCCESSIVE YEARS OF PLANTS THREE OR MORE YEARS OLD. DATA FOR 1913, 1914, AND 1915

Plant	Value of a		
	1913	1914	1915
A	19.2	19.2	{ 18.6
B	19.3	18.0	{ 19.3
C	21.5	21.8	{ 18.5
E_3	20.6	20.8	{ 17.6
E_{22}	23.0	23.6	{ 23.0
			{ 21.8
			{ 20.8
			{ 20.6
			dead

TABLE 39 gives the values of a for plants of different ages, for the entire F_1 and F_2 population and for the various lines of descent. For the F_1 plants, as a group, the average the first year is 18.8; for the second year is 20.6 and for the third is 21.0; the average

TABLE 39

FLOWER NUMBER PER HEAD (*a*) FOR ONE-YEAR, TWO-YEAR, AND THREE-YEAR-OLD PLANTS

Plants	One year old		Two years old		Three years old		Increase in <i>a</i> from 1 year to 2 years	Increase in <i>a</i> from 2 years to 3 years
	Average <i>a</i>	Number of cases	Average <i>a</i>	Number of cases	Average <i>a</i>	Number of cases		
F ₁ 's.....	18.8	36	20.6	55	21.0	105	+ 0.8	+ 0.4
(A × E ₂₂).....	19.1	9	20.7	10	20.9	35	+ 1.6	+ 0.2
(E ₂₂ × A).....	19.7	5	20.4	6	20.0	11	+ 0.7	- 0.4
(E ₃ × A).....	18.6	6	21.1	8	19.8	12	+ 0.5	- 0.3
(A × E ₃).....	18.4	3	20.3	6	19.1	9	+ 1.9	- 0.8
(C × E ₂₂).....	20.1	4	21.5	5	21.4	16	+ 1.4	- 0.1
(E ₃ × C).....	18.4	4	20.4	6	19.4	7	+ 2.0	- 1.0
(C × E ₃).....	19.3	2	21.0	8	20.5	8	+ 1.7	- 0.5
(A × C).....	18.1	3	19.8	6	20.0	7	+ 1.7	+ 0.2
F ₂ 's.....	18.5	63	19.4	23	—	—	+ 0.9	—
(A × E ₂₂)-4-....	20.5	10	20.0	3	—	—	- 0.5	—
(E ₂₂ × A)-10- Ser. I.....	17.6	11	18.2	10	—	—	+ 0.6	—
(E ₂₂ × A)-10- Ser. II.....	17.1	15	—	—	—	—	—	—
(E ₃ × A)-4-Ser. I.....	19.7	10	19.5	10	—	—	- 0.2	—
(E ₃ × A)-4-Ser. II.....	19.2	17	—	—	—	—	—	—

increase of the second year over that of the first is just twice that of the third year over the second year. The F₂ generation has been studied only for the first and second year of growth, but has shown practically the same increase as did the F₁.

In regard to the behavior of the rate of decrease in successive years, it has been pointed out earlier in the paper that the rate of decrease becomes less as the blooming season becomes longer. Older plants are more vigorous than one-year-old plants and bloom longer. Because of this fact the rate of decrease becomes less as the plant grows older. The question whether various lines of descent are exhibiting diverse types of behavior, which are, however, characteristic of particular lines, will be more fully considered later.

6. VARIATION IN RANGE AND DISTRIBUTION OF MODAL NUMBERS

A survey of the facts regarding the maxima or modal numbers in chicory are of interest in relation to the question of specificity of flower number.

From data taken on an average of every third day throughout the period of bloom, it often appears, as may be illustrated in TABLE 10, that a well-pronounced maximum or mode is in evidence. In this particular instance there are 86 heads with 19 flowers per head, and about this mode there is quite a regular chance distribution. In other cases, the distribution is less regular and a mode is less pronounced. In no case, however, has there appeared evidence of a strongly bimodal distribution. Of course, data on all heads blooming on a plant would perhaps bring out the modal number more prominently. The collection of data during only a part of the blooming period would, of course, give quite different modes for any plant which exhibits a rate of change.

The range and distribution of the modal values for various groups of plants are given in TABLE 40. Several points are clearly indicated. The range of individual variability of modal numbers is rather wide and extends from 14 to 22. Interannual partial variability exists, as shown in the first section of the table, which presents data of a single generation in the first, second, and third years of growth. The distribution is somewhat irregular and the number of plants observed is not as large as one might wish, but the evidence is quite clear that the mode for a plant actually shifts to higher values at least during the first three years of growth.

TABLE 40
DISTRIBUTION OF MODES FOR FLOWER NUMBER PER HEAD FOR INDIVIDUALS OF VARIOUS GENERATIONS AND LINES OF DESCENT

Plants	Distribution of modes									Number of plants	Average mode
	14	15	16	17	18	19	20	21	22		
F ₁ First year.....	.....	3	9	7	13	2	3	1	.....	38	18.4
Second year.....	.....	.....	2	4	2	26	11	7	.....	52	19.1
Third year.....	.....	.....	1	4	1	30	11	15	1	63	19.5
F ₃ and F ₄											
(A × E ₂₂)-4-....	.....	.....	.....	5	10	12	7	3	.....	37	18.8
(A × E ₂₂)-9-....	2	41	31	41	3	.....	.....	.....	.....	118	16.0
(E ₂₂ × A)-10-..	.....	10	31	84	7	11	.....	.....	.....	143	16.8
Summary.....	2	51	62	130	20	23	7	3	.....	298	16.8
R's 1916.....	1	13	12	17	14	10	9	3	.....	79	17.4

The second section of the table presents data for the F₃ and F₄ generations of three main lines of descent in the first year of

bloom. Here family differences are to be noted: highest values are seen in family $(A \times E_{22}) - 4 -$ and lowest values are seen in family $(A \times E_{22}) - 9 -$. It will be seen by comparison with TABLE 48 that these modes are high or low quite in agreement with values of a .

The modes for the 1916 crop of the variety red-leaved Treviso exhibit a rather wide range of variability, and the most frequent class is not strongly indicated but appears to be at 17. It will be shown later that the values of a for these plants (TABLE 42) are relatively high, although the range of variability of flower number is wide. The distribution for the whole season is somewhat skew and the low modal values are not an indication of the seasonal performance.

No attempt has been made to mass indiscriminately the total counts made into a general table. It is obvious that such a treatment would cover up individual and line differences, and the final value thus obtained would be modified by the proportionate number of individuals in the different races represented.

IV. CHARACTERISTICS OF FLOWER NUMBER IN THE VARIETY RED-LEAVED TREVISO

This variety is one of remarkable vigor of growth. Grown from seed sown in pans in a greenhouse during January there is vigorous and rapid growth, giving large rosette leaves of extremely robust habit and a large much-branched stem. The mature plants have been from 4 1/2 to 6 1/2 feet tall (see Fig. 1, Stout '17). When thus grown from seed the plants are annuals. The exceedingly vigorous growth usually reaches full maturity in late summer and early autumn and the plants are usually through blooming before the first late-autumn freeze.

The race grown has exhibited a type of teratological development which consists in the production of two stems sometimes completely separated above the crown, but usually united and somewhat twisted for a distance, above which the two merge into a single apparently normal stem. The fasciation usually does not extend to the flower branches and does not directly affect the individual flower heads. The extent of fasciation, the leaf shape, and the degree of pigmentation in this strain all show considerable

variation, but the plants grown in all three years were quite similar in general vigor and habit of growth, although there was more or less variation in the number of branches and the length of the flowering period.

Data on flower number in this variety have been obtained from two parent plants of 1913, and from three generations (1914, 1915, and 1916 crops) derived by further intravarietal breeding. Until the summer of 1915 all plants (with the exception of one feebly self-fertile plant in 1915) were found to be self-sterile. The variety was kept in culture by crossing plants (usually immediate sister plants) that were cross-compatible.

As a result of the vigorous and robust growth in the lines grown of this variety as many as 2,000 to 3,500 flower heads per plant were produced. At the climax of development 100 or even 150 heads opened on a single plant in a single day. The period of bloom was also somewhat extended, but data were not used unless a plant completed its bloom before the first autumn freeze.

TABLE 41 presents data for one of these plants. For this plant the period of bloom extended from July 14 to October 21. There is a decided decrease in both daily range and average. The partial variability seen in the entire range from 31 to 7 was the greatest in both directions seen in any plant of this variety.

Of the crop of 1913, grown from commercial seed, there are data for the two plants which were crossed in obtaining seed from which all cultures were derived. For one of these the values obtained were $a = 19.5$, $b = -0.084$, and the range was 23-12; for the other plant $a = 17.4$, $b = -0.081$, and the range was 19-13. With respect to values of a , these two parent plants were somewhat diverse.

For the 1914 crop, data were obtained from nine plants: these gave values of a ranging from 18.6 to 20.8, with average of 19.8 ± 0.67 . As shown in TABLE 42, the values of these plants are quite well distributed about the value of the parent having highest value of a .

In 1915, offspring were grown from crosses involving four sister plants (of the 1914 crop) for which the values of a were almost identical and were quite of the average. The average values for each line of descent according to immediate parentage

TABLE 41
SEASONAL DISTRIBUTION OF NUMBER OF FLOWERS PER HEAD FOR A PLANT OF RED-LEAVED TREVISO. DATA FOR 1916

Number of flowers per head	July						August											September											October								
	14	17	20	24	26	29	1	4	7	9	12	15	18	21	23	26	30	5	7	9	13	15	18	20	23	26	28	2	4	7	10	13	16	21			
7															1																						
8																																					
9																				2	1					1											
10																					1	2		1			1										
11																					2		2					1			1		2	1			
12															1						1	4	2	1	1		2	2			1						
13																	1	2	1	2	1	1	1	2	2				1				1				
14															1	1	1		2	1			2	1	1		1	1	1		2	1		1			
15										2	1	1	2	1	1	1	3	4	3		2		3	1	4	1	1	2	1	1	1	2					
16												3	2	1	1	1	4	2		2	1	1	2	2	2	2	2	1	1	1		4					
17								1	1	1	3	3	1	3	3				4	2	1		1	1		1	1	1			1	1		1			
18				1	1	2	1		3	1	2	1	1		2			2		1					1	3	2				1		1				
19				3		1	2	2	2	3	1	1	1	4							2									1							
20			3	6	3	4	5	7	3	2	3		3	1																	1						
21			2		5	3	1		1	1					1																						
22		2	2		1							1				1																					
23		3	1																																		
24	1	2	2				1																														
25		2																																			
26																																					
27		1																																			
28	1																																				
29																																					
30																																					
31	1																																				
Averages.	27.7	23.8	21.7	19.5	20.5	19.8	20.1	19.5	19.0	18.2	18.1	17.3	17.6	17.8	16.4	16.7	15.1	15.4	15.4	14.8	14.0	11.9	14.3	13.5	14.7	15.3	14.8	14.0	14.5	17.5	14.5	15.8	13.7	13.7			

$$\begin{aligned}
 [o] &= 16.9 & a &= 21.3 \\
 [ol] &= -74.82 & b &= -0.089 \\
 [l] &= 49 & t &= 99 \\
 [l^2] &= 839.35
 \end{aligned}$$

were all above 20 (see TABLE 42) and the range had shifted to decidedly higher values than had previously appeared. One plant gave a rather low value of *a*, 16.9. The complete sterility of all but one of these plants prohibited the study of selection for high or low values in uniparental offspring. The very prevalent cross-incompatibility also limited the possibility of testing such selection in biparental heredity. However, crosses were made from which six different progenies were grown in 1916.

TABLE 42

DISTRIBUTION OF VALUES OF FLOWER NUMBER OF FIRST DAY OF BLOOM (*a*) FOR THE VARIETY RED-LEAVED TREVISO. DATA FOR 1913, 1914, 1915, AND 1916

Series	Distribution of values of <i>a</i>																		Number of individuals	Average <i>a</i> of series	σ of series	<i>a</i> of parents		
	14.5	15.0	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.5	20.0	20.5	21.0	21.5	22.0	22.5	23.0					23.5	24.0
1913	.	.	.	.	.	.	I	.	.	.	.	I	.	.	.	.	.	.	.	.	2	18.5	—	—
1914	.	.	.	.	.	.	.	.	.	I	I	4	2	I	.	.	.	.	.	.	9	19.8	± 0.67	{ 19.5 17.4
1915																								
<i>R</i> _{1,2,3}	.	.	.	.	.	.	.	.	.	.	I	I	I	I	2	2	I	.	.	.	9	20.8	± 0.99	{ 19.5 19.7 ²
<i>R</i> ₄	.	.	.	.	.	I	.	.	.	.	I	.	I	I	I	.	I	I	I	.	8	20.8	± 2.15	{ 19.8 ¹ 19.9
<i>R</i> ₅	.	.	.	.	.	.	.	.	I	I	2	2	5	I	.	3	I	I	I	I	19	20.6	± 1.56	{ 19.8 ¹ 19.7 ²
1916																								
<i>R</i> ₇	.	.	.	.	.	.	.	3	.	2	.	2	3	.	.	I	I	.	.	.	12	19.5	± 1.52	no data
<i>R</i> ₈	.	I	.	.	2	.	3	I	2	I	I	I	4	I	.	.	.	.	.	.	17	18.4	± 1.79	{ 19.0 19.8
<i>R</i> ₉	.	.	.	.	.	I	3	5	2	3	2	3	3	.	.	.	.	.	I	.	23	18.6	± 1.37	{ 21.7 ³ 19.2
<i>R</i> ₁₀	.	.	.	.	.	I	2	.	.	2	.	.	2	2	.	.	.	.	.	.	9	19.0	± 1.49	{ 19.0 20.8 ⁴
<i>R</i> ₁₁	.	.	.	.	I	I	I	I	I	.	2	I	3	5	2	I	I	.	.	.	20	19.7	± 1.64	{ 21.7 ² no data
<i>R</i> ₁₂	.	.	.	.	.	.	.	.	.	.	.	2	6	3	I	4	I	.	.	.	17	20.8	± 0.77	{ 21.8 ² 22.8

A glance at the results recoreded in TABLE 42 shows that the ranges of values per plant and the averages for the different series are somewhat different. The lowest average of 18.4 ± 1.79 seen in series 8 is lower than the average of the generations grown in the previous two years. The range is also lower. The immediate parents of this series were of lower than average rank, but the offspring average still lower. The highest average (20.8) seen in series 12 is the highest realized in any of the 1916 series and is

quite of the average of the previous year. The parents of this series were plants of high values. While the series showed some regression, the variability of ± 0.77 was low and the average value of a was higher than that of other series from parents of lower value. The results obtained in these two lines suggest that in this variety lines of descent may differ and that such differences may be high or low according to the performance of the ancestry.

TABLE 43

DISTRIBUTION OF VALUES FOR RATE OF DECREASE (b) FOR THE VARIETY RED-LEAVED TREVISO.
DATA FOR 1913, 1914, 1915, AND 1916

Series	Distribution of values of b																				Number of individuals	b of parents	Average b of series	
	+0.010	0.000	-0.010	-0.020	-0.030	-0.040	-0.050	-0.060	-0.070	-0.080	-0.090	-0.100	-0.110	-0.120	-0.130	-0.140	-0.150	-0.160	-0.170	-0.180				-0.190
1913.....										2												2	—	-0.082
1914.....			2							2	2	1		1	1							9	{ -0.084 -0.081	-0.075
1915																								
$R_{1,2,3}$						1			1		1	2	3	1								9	{ -0.072 -0.081 ¹ -0.086 ²	-0.087
R_4								1	1	1	1	1	1		2							8	{ -0.007 -0.086 ²	-0.093
R_5										1	6	2	3	2	1	1		1	1		1	19	{ -0.081 ¹	-0.110
1916																								
R_7					1	2		4	3		1		1									12	no data	-0.057
R_8		1		1	1		2	3		3	2	1	1	2								17	{ -0.059 -0.083 -0.092 ³	-0.051
R_9							3	6	3	3	3	3				1			1			23	{ -0.088 -0.083 -0.087 ⁴	-0.075
R_{10}				1			2	2	1	1	2											9	{ -0.093 ²	-0.058
R_{11}					2	2	1	1	4	4		3	2			1						20	no data	-0.071
R_{12}										5	3	5		2	1		1					17	{ -0.087 ⁴ -0.124	-0.086

As shown in TABLE 43 the values of b were more variable than the values of a . The characteristic performance gave minus values for the rate of change and there was on the whole less variability than was seen in the hybrid generations reported above; here there were no cases of $+$ values, and only one plant in the 0.000 class.

In this variety the branching of laterals was very complete, as shown in PLATE 13, *A* and *B*, and there were, as a rule, rather few heads in clusters such as are shown in PLATE 13, *C* and *D*.

This habit and the abundant branching which result in the production of such large numbers of heads presumably give opportunity for the development of heads of such ultimate laterals as might be suppressed in a less robust growth, as is seen in dwarf races. There should be opportunity to observe, in such a race, the lowest possible range of flower number for the species. The chance for development of partial variability is most favorable. The observations indicate that this is the case. In TABLE 44 are shown the ranges in number per head for all plants studied in this variety. The highest flower number per head extends from 31 to 19 and there were 40 plants out of 144 that had produced some heads with 25 or more flowers.

TABLE 44

RANGE OF FLOWER NUMBER PER HEAD FOR ALL PLANTS OF THE VARIETY RED-LEAVED
TREVISO

Number of plants	Maximum flower number	Minimum flower number		Difference between maximum and average minimum
		Range	Average	
1	31	—	7.0	24.0
1	30	—	13.0	17.0
3	28	15-11	13.0	15.0
7	27	13-10	11.4	15.6
11	26	12-7	10.1	15.9
17	25	16-9	12.0	13.0
26	24	14-5	10.7	13.3
27	23	17-6	11.2	11.8
26	22	14-7	10.9	11.1
17	21	14-9	11.1	9.9
6	20	13-10	11.3	8.7
2	19	13-11	12.0	7.0

Furthermore, the low numbers range as low as 5 and in every class grouped together for a particular high number some plants produced one or more heads of eleven or twelve. The plant with the highest number of flowers per head (31) produced heads ranging as low as 7. The complete record of data for this plant is given in TABLE 41.

This variety is characterized by rather wide extremes of partial variability and by high values of *a* and *b*.

V. CHARACTERISTICS OF FLOWER NUMBER IN A HYBRID GENERATION OF A CROSS BETWEEN PLANTS OF RED-LEAVED TREVISO AND A WILD PLANT (A)

The plants of this hybrid generation were all of vigorous vegetative growth. They were scarcely as tall as typical plants of the red-leaved Treviso, but they were more abundantly branched from the base of the main stem. The total number of flower heads averaged about the same as for the red-leaved Treviso.

Data were collected from 50 plants of this generation. For these the range of observed numbers per head extended from 28 to 10 (TABLE 45). This range is less both for highest and lowest number than in the red-leaved Treviso. The plant with highest number, 28, also gave numbers as low as 11, thus exhibiting in its partial variability almost the entire range observed. For highest numbers alone the individual variability ranged from 28 to 19; for lowest numbers it ranged from 15 to 10. Greater differences exist in the highest numbers than in the lowest, quite as has been noted for other cultures of chicory.

TABLE 45

RANGE OF FLOWER NUMBER PER HEAD OF PLANTS OF THE F_1 GENERATION OF THE CROSS BETWEEN RED-LEAVED TREVISO AND A WILD PLANT (A)

Number of plants	Maximum flower number	Minimum flower number		Difference between maximum and average minimum
		Range	Average	
1	28	—	11.0	17.0
2	25	15-10	12.5	12.5
2	24	15-12	13.5	10.5
7	23	14-12	12.7	10.3
10	22	15-11	12.7	9.3
12	21	14-11	12.3	8.7
15	20	14-10	11.3	8.7
1	19	—	11.0	8.0

The values a and b have been computed for 12 plants of this hybrid generation and these are given in TABLE 46. These are sister plants having for seed parent a plant of red-leaved Treviso (*R ser* 1, no. 6) whose performance gave a value of 21.5 for a and -0.091 for b . These values are quite the average for the plants of this race grown in 1916 (see TABLE 42).

As shown in TABLE 46, the values of a for these 12 plants ranged from 16.6 to 21.4, with the average at 19.1. All 12 plants gave minus values for b .

TABLE 46

VALUES FOR TWELVE F_1 HYBRIDS OF A CROSS BETWEEN A PLANT OF THE RED-LEAVED TREVISO AND A WILD PLANT (A)

Pedigree	[ϕ]	[t]	[ϕt]	[t^2]	a	b	t
RA ser. 3—no. 19.....	15.2	48	— 21.58	701.00	16.6	— 0.030	91
“ 13.....	17.0	48	— 15.05	740.21	18.0	— 0.020	91
“ 21.....	17.0	47	— 23.75	781.87	18.4	— 0.029	94
“ 15.....	17.5	52	— 17.89	932.42	18.5	— 0.019	97
“ 9.....	16.6	50	— 34.10	690.03	18.8	— 0.048	90
“ 24.....	17.7	42	— 22.87	611.89	19.2	— 0.036	83
“ 10.....	18.1	52	— 25.35	936.72	19.3	— 0.027	99
“ 8.....	17.4	48	— 34.19	856.32	19.3	— 0.040	97
“ 2.....	19.2	46	— 11.26	675.65	20.0	— 0.017	87
“ 22.....	17.6	48	— 40.51	432.25	20.2	— 0.055	91
“ 16.....	18.2	53	— 39.36	926.86	20.4	— 0.041	103
“ 18.....	17.9	56	— 67.04	1072.15	21.4	— 0.062	110

VI. SELECTION AND HEREDITY: CHARACTERISTICS OF DIFFERENT PROGENIES AND VARIOUS LINES OF DESCENT DERIVED FROM A CROSS BETWEEN A WILD PLANT (A) AND PLANTS OF THE VARIETY BARBE DE CAPUCIN

It would seem that the computed value for the first date of bloom (a) which is derived from a considerable amount of data obtained during the entire period of growth is the most adequate single value obtainable that is sufficiently characteristic to serve as a basis for judgment of the effects of selection and of heredity. The value of the rate of change (b) can also be used as a value for comparisons.

I. GENERAL COMPARISON OF PROGENY WITH IMMEDIATE PARENTS AS TO VALUES OF a AND b

Whether flower number is directly inherited as such or indirectly inherited through its relation to types of vegetative habit of growth, some clue to the type or degree of heredity may be gained by the comparison of the performance of offspring with the values of the immediate parents.

With the appearance of a few self-fertile plants in the F_1 generation, it was possible to grow self-fertilized lines of descent of uniparental lineage and data from such lines admit of a comparison of performance. On account of the self-sterility of a large number of the various progenies (about 50 per cent.), it was not possible to make extreme + and — selections.

The F_1 generation of the cross wild white-flowered $\times$ Barbe de

Capucin was of biparental descent. The summaries for comparison with the immediate parents are given in TABLE 47. The values of a for the F_1 are from data collected in the third year of growth and are averaged for all sister plants of a particular cross.

TABLE 47

AVERAGE FLOWER NUMBER FOR FIRST DAY OF BLOOM (a) FOR PARENTS AND THEIR F_1 OFFSPRING

Parents			F ₁ offspring		Difference between parents and offspring
a	a	Average a	Number of plants	Average a	
C , 21.7	E_{22} , 23.3	22.5	19	21.4	- 1.1
C , 21.7	E_3 , 20.7	21.2	15	20.0	- 1.2
A , 19.2	E_{22} , 23.3	21.2	46	20.1	- 1.1
A , 19.2	C , 21.7	20.4	7	20.0	- 0.4
A , 19.2	E_3 , 20.7	19.9	21	19.5	- 0.4

It is rather striking that while in every case the average of the offspring is below that of the average for the two parents, yet the higher the average of the parents the higher is the average of the offspring. The fact that the average of the offspring is lower than that of the two parents suggests that the immediate parents gave values that are high for the races involved and that the offspring show regression. It will be seen that the difference between the average flower number per head of parent and offspring is the greater the higher the value of the parents. Accordingly, if one used parents with very low flower number, in all probability the offspring would give a somewhat higher average flower number than their parents.

Further and more exact comparison of progeny with immediate parent can be made in the three main lines of uniparental descent constituting the F_2 , F_3 , and F_4 generations. TABLE 48 presents such data, indicating the pedigree, the distribution for values of a , the variability measured by the standard deviation, the value of a for the immediate parent, and the standard deviation of the parent series (the series of sister plants to which the particular parent belonged).

A glance down the columns of the frequency distribution shows that the three lines of descent present, on the whole, values that are rather uniform for each line. A comparison of the values of

a for a series with that of the immediate parent shows a marked agreement. Frequently, inside of a line, the offspring deviate somewhat from the values of the line, or regress toward the average

TABLE 48
DISTRIBUTION OF VALUES OF *a* IN PEDIGREED LINES IN F₁, F₂, F₃ AND F₄ GENERATIONS

Generation	Pedigree	Frequency distribution for values of <i>a</i>														Offspring			Parent					
		14.5	15.0	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.5	20.0	20.5	21.0	21.5	22.0	22.5	23.0	Number	Average <i>a</i>	σ	<i>a</i>	σ of series
F ₁	(<i>A</i> × <i>E</i> ₂₂) and (<i>E</i> ₂₂ × <i>A</i>)	..	..	..	..	..	3	2	..	1	1	1	2	1	1	1	1	..	1	14	19.9	±2.07	....	....
F ₂	(<i>A</i> × <i>E</i> ₂₂)-4-	..	..	..	..	..	..	..	..	1	1	1	..	3	1	3	1	..	..	10	20.5	±0.92	19.9	±2.07
F ₃	" -4-3-	..	..	..	..	..	..	..	1	1	..	3	3	3	2	2	..	..	..	12	20.0	±0.94	21.6	±0.92
F ₄	" -4-3-11-	..	..	..	..	..	..	..	..	2	..	2	1	1	2	2	2	..	..	10	20.4	±1.11	21.4	±0.94
F ₃	" -4-6-	..	..	..	..	..	..	1	1	1	2	..	..	..	1	..	..	..	..	6	18.9	±1.13	19.4	±2.07
F ₄	" -4-6-3-	..	..	..	..	..	..	..	1	1	2	1	2	1	1	1	..	..	..	9	19.7	±0.97	20.7	±1.13
F ₂	(<i>A</i> × <i>E</i> ₂₂)-9-	..	..	..	..	..	2	..	..	1	..	..	..	..	..	..	..	..	..	3	17.2	±1.19	—	±2.07
F ₃	" -9-4-	..	..	2	2	4	3	1	2	..	..	..	..	..	..	..	..	..	..	14	16.4	±0.81	—	±1.19
F ₄	" -9-4-4-	..	..	3	1	2	1	2	2	..	..	..	..	..	..	..	..	..	..	9	16.2	±1.02	16.3	±0.81
	" -9-4-10-	..	2	3	3	..	2	..	..	..	..	..	..	..	..	..	..	..	..	10	15.5	±0.62	17.9	±0.81
	" -9-4-11-	..	..	1	1	..	1	..	1	..	..	..	..	..	..	..	..	..	..	4	16.7	±1.51	16.5	±0.81
F ₃	" -9-5-	..	..	1	3	..	6	..	2	1	..	..	..	..	..	..	..	..	..	13	16.6	±0.86	16.5	±1.19
F ₄	" -9-5-1-	..	..	1	1	..	2	..	..	..	..	..	..	..	..	..	..	..	..	4	16.0	±0.66	16.6	±0.86
	" -9-5-6-	..	..	2	2	6	5	7	4	3	..	..	..	..	..	..	..	..	..	29	16.8	±0.82	16.8	±0.86
	" -9-5-12-	..	..	5	3	10	12	4	11	3	..	..	..	..	..	..	..	..	..	35	16.9	±0.62	17.7	±0.86
F ₂	(<i>E</i> ₂₂ × <i>A</i>)-10-	..	..	2	1	1	3	4	11	3	..	..	..	1	..	..	..	..	..	26	17.3	±0.99	18.8	±1.39
F ₃	" -10-8-	..	..	..	..	..	1	2	3	3	3	2	1	..	..	..	..	..	..	12	18.3	±0.62	17.7	±0.99
F ₄	" -10-8-14-	..	..	1	1	1	1	4	4	3	1	..	1	..	..	..	..	..	..	16	17.6	±0.91	18.9	±0.62
	" -10-8-15-	..	..	..	..	..	1	2	5	2	3	1	1	1	..	..	..	..	..	15	18.6	±0.69	17.8	±0.62
F ₃	" -10-13-	..	..	..	..	..	4	5	3	3	1	..	..	..	..	..	..	..	..	16	17.9	±0.59	17.7	±0.99
F ₄	" -10-13-5-	..	..	..	..	..	5	6	6	2	..	..	..	..	..	..	..	..	..	19	17.3	±0.51	18.3	±0.59
	" -10-13-12-	..	..	..	..	..	2	6	6	1	2	..	..	..	..	..	..	..	..	23	17.8	±0.56	18.1	±0.59
	" -10-13-13-	..	..	1	5	7	9	5	1	..	..	..	..	..	..	..	..	..	..	28	16.4	±0.66	17.1	±0.59
F ₃	" -10-14-	..	..	..	..	1	2	1	1	3	..	..	..	..	..	..	..	..	..	7	18.1	±1.15	17.7	±0.99
F ₄	" -10-14-6-	..	..	..	..	..	1	..	3	1	1	1	1	..	..	..	..	..	..	7	18.4	±0.88	19.2	±1.15

and are hence not in close agreement with the actual value of the parent. There are, however, numerous cases of almost exact agreement.

It is also to be noted that there is a decided reduction in vari-

ability of various series of F_2 , F_3 , and F_4 generations over that of parent series of the F_1 . For the latter the standard deviation is ± 2.07 ; for the former the values are mostly less than ± 1.00 .

TABLE 49
DISTRIBUTION OF VALUES OF b IN PEDIGREED LINES IN F_1 , F_2 , F_3 , AND F_4 GENERATIONS

Generation	Pedigree	Frequency distribution of values of b																Offspring		b of parent						
		+0.020	+0.010	0.000	-0.010	-0.020	-0.030	-0.040	-0.050	-0.060	-0.070	-0.080	-0.090	-0.100	-0.110	-0.120	-0.130	-0.140	-0.150		-0.160	-0.170	-0.180	-0.190	Num-ber	Average b
F_1	$(A \times E_{22})$ and																									
F_2	$(E_{22} \times A)$																									
F_3	$(A \times E_{22})-4-$																									
F_4	" -4-3-																									
F_3	" -4-3-11-																									
F_4	" -4-6-																									
F_3	" -4-6-3-																									
F_4	" -4-6-3-																									
F_2	$(A \times E_{22})-9-$																									
F_3	" -9-4-																									
F_4	" -9-4-4-																									
	" -9-4-10-																									
	" -9-4-11-																									
F_3	" -9-5-																									
F_4	" -9-5-1-																									
	" -9-5-6-																									
	" -9-5-12-																									
F_2	$(E_{22} \times A)-10-$																									
F_3	" -10-8-																									
F_4	" -10-8-14-																									
	" -10-8-15-																									
F_3	" -10-13-																									
F_4	" -10-13-5-																									
	" -10-13-12-																									
	" -10-13-13-																									
F_3	" -10-14-																									
F_4	" -10-14-6-																									

The variability of sister plants of a series decreases with line breeding.

The performances of these lines of descent and pedigreed series with respect to rate of change (b) are given in TABLE 49.

The frequency distribution is given for classes of 0.010 extent. Here, as for values of flower number for the first day of bloom (*a*) the lines show some noticeable characteristic differences; for line descending from the F_1 plant ($A \times E_{22}$) no. 4 the — values were most in evidence. In the other two lines a considerable number of plants exhibited + values. The heredity of the type of seasonal change is in general indicated by line performances. In respect to immediate parentage, the agreement is less close than for values of flower number. There has been no attempt rigidly to select for various values of rate of change. That the performance is more sporadic for rate of change than for flower number will be further indicated in the study of various races.

2. DETAILED ANALYSIS OF SIX RACES AS TO INHERITANCE OF FLOWER NUMBER PER HEAD

In the F_3 and F_4 generations of the family with the original parentage wild white-flowered (A) $\times$ Barbe de Capucin (E_{22}), it became evident that the pedigreed breeding in lines had resulted in the development of several types, races, or elementary species which differed from each other most decidedly in habit of growth. This gave opportunity for the study of the flower number in rather widely diverse races. Comparisons can be made with reference to the relation of various habits of growth to performance in flower production. The detailed records of lines of parentage also give opportunity for further analysis of the influence of selection and the degree to which heredity is in evidence.

A. *The history and characteristics of a semi-dwarf, sparsely branched race (race 1, or line ($A \times E_{22}$)—4-3—).* In mature development for the first year of growth this race was characterized by low stature (1 1/2 to 2 1/2 feet tall) and by a sparse and coarse branching habit. The branches were very brittle, and there was a very general death of the branches due to susceptibility to a bacterial or fungous disease. The death of the tips of the branches added considerably to the dwarf-like appearance and decreased the total number of flower heads that came to bloom. Twelve plants of the F_3 and thirty-one plants of the F_4 of this race were quite uniform in the general vegetative habit of growth. In the rosette stages, however, the plants which later made smallest

growth were decidedly dwarfed. The general habit of this race is well shown in PLATE II, which also shows the effects of the tip-rot.

TABLE 50

STATISTICAL CONSTANTS (DISCUSSED PAGES 380-385) FOR TWO GENERATIONS (F_3 AND F_4) OF A SEMI-DWARF, SPARSELY BRANCHED RACE (RACE I) WITH THOSE FOR THE IMMEDIATE ANCESTRY

	Pedigree	$[o]$	$[t]$	$[ol]$	$[t^2]$	a	b	t
Ancestry	$F_1. (A \times E_{22})$ no. 4	18.5	21	-10.22	150.33	19.9	-0.066	41
	$F_2. (A \times E_{22})-4-$ no. 9	17.6	26	-13.18	296.63	18.7	-0.044	58
	" 6	18.3	10	-5.56	50.00	19.4	-0.109	22
	" 7	17.9	18	-17.72	145.92	20.1	-0.121	35
	" 8	18.2	14	-10.52	71.40	20.3	-0.153	27
	" 4	17.9	19	-19.82	155.54	20.4	-0.127	41
	" 1	18.1	40	-36.47	538.60	20.9	-0.068	77
	" 2	19.6	20	-13.81	181.87	21.0	-0.073	41
	" 5	19.8	28	-12.39	289.55	21.2	-0.056	55
	" 10	19.7	21	-15.89	196.53	21.4	-0.083	42
	" 3	19.3	19	-18.45	148.85	21.6	-0.120	37
Race I.	$F_3. (A \times E_{22})-4-3-$ no. 6	17.0	23	-10.32	205.13	18.2	-0.052	47
	" 9	17.0	18	-19.54	141.36	18.6	-0.142	38
	" 10	17.5	33	-17.95	297.95	19.5	-0.060	63
	" 8	18.4	15	-10.40	105.69	19.8	-0.096	33
	" 7	17.9	14	-12.90	78.78	20.2	-0.163	31
	" 1	19.8	14	-1.91	92.00	20.2	-0.031	35
	" 2	19.1	15	-7.75	98.82	20.3	-0.077	37
	" 12	18.3	33	-29.45	400.21	20.7	-0.074	68
	" 3	18.9	14	-11.23	82.29	20.7	-0.132	34
	" 4	19.1	24	-18.47	235.71	21.0	-0.078	55
	" 5	18.7	15	-18.45	116.38	21.1	-0.158	40
	" 11	18.6	33	-34.12	403.09	21.4	-0.085	71
	$F_4. (A \times E_{22})-4-3-11-$ no. 18	17.8	25	-8.40	269.89	18.6	-0.031	60
	" 15	16.8	25	-26.26	337.00	18.8	-0.079	58
	" 3	18.0	34	-24.22	498.08	19.7	-0.049	75
	" 20	18.8	31	-13.72	432.56	19.8	-0.032	69
	" 25	18.2	25	-24.23	298.39	20.2	-0.081	59
	" 41	19.7	33	-12.72	372.00	20.8	-0.034	65
	" 21	19.3	29	-18.49	318.25	21.0	-0.057	56
	" 9	20.2	28	-9.29	288.10	21.2	-0.034	55
	" 8	19.4	16	-15.55	98.62	21.9	-0.156	33
	" 24	19.4	16	-15.38	97.75	21.9	-0.156	31

A most characteristic feature of flower number per head in this race, as seen in F_3 and F_4 , is its high value. The average number (TABLE 50) per head $[o]$ is high, which indicates that heads with high flower number were strongly in evidence. There was a pronounced tendency to produce some heads with extra high numbers. In the F_3 series $(A \times E_{22})-4-3-$ of 12 plants there

were six plants, having some heads of 24 or more flowers (see TABLE 51). One plant (no. 12) produced a head of 33 flowers, other plants had heads of 27, 26, and 25 flowers. For the F_4 crop of 31 plants data were collected from 10 plants that were least affected by the tip-rot. These, likewise, showed a tendency to produce a few heads with unusually high numbers per head: seven of the ten plants had some heads with 24 or more flowers each. For no plant was the highest number less than 21. The minimum number in any head for these plants, however, was quite as low as that ordinarily observed. In this race irregular and sporadic variations in partial intra-annual variability occurred, giving a few heads with high numbers. The lowest values realized in a plant during a season were, however, quite or almost as low as were seen in series having no such high numbers.

TABLE 51

RANGE OF VARIABILITY OF FLOWER NUMBER PER HEAD OF ONE-YEAR-OLD PLANTS OF THE F_3 AND F_4 GENERATIONS OF RACE I

Number of plants	Maximum flower number	Minimum flower number		Difference between maximum and average minimum
		Range	Average	
$F_3.$ ($A \times E_{12}$)-4-3-				
1	33	—	12.0	22.0
1	27	—	13.0	14.0
1	26	—	12.0	14.0
1	25	—	15.0	10.0
2	24	13-11	12.0	12.0
3	23	15-10	11.7	11.3
2	22	—	14.0	8.0
1	21	—	13.0	8.0
$F_4.$ ($A \times E_{22}$)-4-3-11-				
1	26	—	12.0	14.0
3	25	15-11	13.3	11.7
3	24	16-13	14.3	9.7
2	23	15-11	13.0	10.0
1	22	—	12.0	10.0

The general tendency in this race, however, is toward high numbers per head. The values for $[o]$ and for a computed from all the data are consistently high. In respect to seasonal change, all plants of this race exhibited a marked decrease, as may be seen in the values of b given in TABLE 50. The performance with respect to terminals and laterals was quite as is most typical of the species.

The record of pedigree for the two series (F_3 and F_4) of this

race shows that the descent has been consistently from the plants having highest values of a . For the parent of the F_4 series (which was $(A \times E_{22}) - 4-3 - no. 11$), the value of a was 21.4, which was the highest of the series. The parent in the F_2 was plant $(A \times E_{22}) - 4 - no. 3$; the value of a for it was 21.6, also the highest of the series. The value of a for the F_1 plant used as a parent was 19.9. The values of a for the two original parents was as follows: for the wild white-flowered plant A , 19.2 in 1913 and 19.3 in 1914; for the plant of Barbe de Capucin, E_{22} , 23.0 in 1913 and 23.6 in 1914 (these values are of slightly higher relative value as the plants are older than one year).

The race is, therefore, one of high average values, the average of a being above 20.0. Selection for high values of a has maintained a high average. The race has shown a strong tendency to irregular sporadic partial variability in that high numbers of flowers are frequently developed in a few heads.

B. *The history and characteristics of a dwarf, sparsely branched race (race 2 or line $(A \times E_{22}) - 4-6 -$)*. At the extreme right foreground of PLATE II are shown several characteristic plants of this very decidedly dwarfed race. In general habit of growth and susceptibility to the tip-rot this race is quite like the semi-dwarf just described. It is, however, of much smaller stature and is less branched. Nine plants of the F_3 and twenty of the F_4 have been quite uniform in general appearance when mature. Statistical data on flower number were taken from six plants of the F_3 and from nine plants of the F_4 , these plants being the ones least injured by the tip-rot.

In agreement with the extremely dwarf habit, the total number of heads produced by these plants is low, the average for the nine plants studied of the F_4 being 95 for the entire season of growth. This dwarf race is a sister race of race 1, noted above, in that the two descended from the same F_1 plant $(A \times E_{22}) no. 4$. The number of heads open in any one day was so low that on only one date were 10 heads open in a single day on any of the 1916 crop. The period of bloom was somewhat shortened.

The highest flower number for any head was 22 and the lowest was 12. There was no tendency to the production of extremely high numbers per head for a few heads, as seen in the semi-dwarf

race; the values of $[o]$ and a average slightly lower (TABLES 52 and 48).

All plants of the race showed a seasonal decrease ($-b$) with the characteristic relation of laterals and terminals.

The ancestry of this race diverged from that of the semi-dwarf race in that the F_2 parent selected was a different plant (no. 6) having somewhat lower values of a (19.4) and of $[o]$ (18.3). The selection for this race has not been consistently for lowest values of a , as the plant of the F_3 used as parent ($A \times E_{22}$) - 4-6 - no. 3) was the one having highest values for a . The F_4 has shown an increase of average of a over that of the preceding generation.

TABLE 52

STATISTICAL CONSTANTS FOR TWO GENERATIONS (F_3 AND F_4) OF A DWARF, SPARSELY BRANCHED RACE (RACE 2). ANCESTRY GIVEN IN TABLE 50

Pedigree	$[o]$	$[t]$	$[ot]$	$[t^2]$	a	b	t
$F_3.$ ($A \times E_{22}$) - 4-6 -							
no. 4	16.4	12	- 5.26	68.53	17.4	-0.081	29
" 8	17.1	17	- 9.89	183.26	18.1	-0.055	51
" 5	16.1	26	-36.07	355.68	18.7	-0.099	68
" 10	16.7	32	-36.12	471.30	19.2	-0.077	70
" 1	16.6	14	-16.50	89.29	19.2	-0.183	39
" 3	18.0	22	-31.01	255.64	20.7	-0.121	48
$F_4.$ ($A \times E_{22}$) - 4-6-3 -							
no. 17	17.6	14	- 3.70	92.50	18.1	-0.039	29
" 1	18.1	10	- 3.26	41.57	18.9	-0.079	19
" 16	18.2	12	- 3.40	45.88	19.1	-0.076	21
" 3	17.9	17	- 9.43	131.46	19.1	-0.071	36
" 2	16.8	22	-26.88	205.77	19.7	-0.134	45
" 11	17.7	16	-12.69	90.50	20.0	-0.141	30
" 15	17.6	17	-17.94	113.25	20.3	-0.157	34
" 21	18.2	16	-13.63	97.17	20.5	-0.141	32
" 23	18.6	16	-17.03	100.55	21.3	-0.171	31

The performance of this race indicates that extreme dwarfing in chicory affects decidedly the total number of heads produced, but has no pronounced effect in reducing the average number of flowers per head or in changing the general character of intra-seasonal partial variability as exhibited by minus values of b .

C. *Characteristics of a race exhibiting a second period of growth during a single season (race 3 or line ($A \times E_{22}$) - 9-5 -).* The peculiar and unusual habit of growth seen in this race has already been described and reference made to the illustration (TEXT-FIGURE 1). Detailed data for three plants of this race have

also been presented (TABLES 31, 32, and 33) and discussed as illustrating (1) increase in flower number per head during a period of growth and (2) the fact that values for the second period of growth are lower than those for the first.

For judgment of the general performance of this race, there are data for 35 sister plants and for 15 of these there are also data from the growth of the second period, all of which are given in TABLE 53.

For the period of first growth, it is seen that values for a range from 15.5 to 18.3 with an average of 16.9 ± 0.62 . The values are very uniform and are decidedly low when compared with those of the semi-dwarf race (race no. 1) considered above. The most decided variability of this race is seen in values of rate of change in flower number; these range from -0.048 to $+0.018$. These differences in rate of change did not seem to involve any differences in vegetative habit of growth, in the grouping of flower heads in clusters, or in the total number of heads produced.

Reference has already been made to the general performance of the growth of the second period and to the evidence that the values for such growth are as a whole lower than those of the earlier growth.

In its ancestry, this race descended from an F_1 plant $\{(A \times E_{22}) \text{ no. } 9\}$ from which no data were obtained.

For the parent selected for the F_3 , $(A \times E_{22}) - 9 - \text{no. } 5$, the value of a was 16.5 and that of b was -0.022 . The parent of the F_4 , $(A \times E_{22}) - 9 - 5 - \text{no. } 12$, was one of 13 sister plants whose values for a ranged from 15.2 to 18.0, averaging 16.6 with a standard deviation of ± 0.86 ; its a value was 17.7 (high for the generation) and its b , -0.024 .

As to value of a , the line of parentage has therefore exhibited rather *medium* values.

Considering the value of a for the first period of growth, the values are quite characteristic for the line of descent as a whole (TABLES 27 and 53).

D. *Characteristics and history of a semi-robust brittle-stemmed race (race 4).* The plants of this race are coarsely and somewhat sparsely branched, the branches are thick and very brittle and bear such small leaves as to appear almost leafless. The thirty

TABLE 53

STATISTICAL CONSTANTS FOR ONE GENERATION (F_4) OF A RACE EXHIBITING A SECOND PERIOD OF GROWTH DURING A SINGLE SEASON (RACE 3) WITH THOSE FOR THE IMMEDIATE ANCESTRY. FOR FIFTEEN PLANTS OF RACE 3 CONSTANTS FOR THE SECOND PERIOD OF BLOOM ARE INDICATED IN ITALICS AND ARE GIVEN DIRECTLY BELOW THE VALUES FOR THE FIRST PERIOD OF BLOOM

	Pedigree	[<i>o</i>]	[<i>t</i>]	[<i>ot</i>]	[<i>t</i> ²]	<i>a</i>	<i>b</i>	<i>t</i>
Ancestry	$F_2. (A \times E_{22})-9-$							
	no. 5	15.9	26	- 6.88	327.38	16.5	-0.022	58
	3	15.9	50	-32.47	992.07	16.6	-0.033	113
	1	17.1	54	-31.61	1140.28	18.6	-0.027	115
	$F_3. (A \times E_{22})-9-5-$							
	no. 11	14.4	30	- 8.50	318.00	15.2	-0.027	60
	" 3	14.6	32	- 9.90	412.00	15.5	-0.027	70
	" 5	15.5	40	- 5.28	625.42	15.8	-0.008	84
	" 9	15.1	49	-14.78	935.97	15.8	-0.015	107
	" 7	15.7	31	-11.20	364.38	16.6	-0.029	65
	" 1	15.9	32	- 8.78	378.24	16.6	-0.023	66
	" 4	16.0	30	- 7.22	397.15	16.6	-0.019	75
	" 13	15.9	50	-15.47	946.32	16.7	-0.016	108
	" 10	15.6	44	-20.35	799.37	16.8	-0.027	97
	" 6	15.8	30	-11.02	340.85	16.8	-0.033	64
	" 2	15.3	25	-24.29	244.74	17.7	-0.097	52
	" 12	16.5	51	-24.60	981.17	17.7	-0.024	109
	" 8	16.5	37	-26.59	674.92	18.0	-0.041	93
Race 3	$F_4. (A \times E_{22})-9-5-12-$							
	no. 35	14.6	34	-10.00	392.83	15.5	-0.026	71
	" 18	15.9	32	+ 3.81	411.35	15.6	+0.009	69
	" 9	16.0	34	+ 4.90	381.09	15.6	+0.013	64
	" 24	15.2	27	- 4.19	244.83	15.7	-0.017	51
	" 15	14.9	19	+ 0.05	119.32	14.9	0.000	37
	" 38	15.7	35	- 2.36	429.14	15.9	-0.006	69
	" 30	15.0	22	+ 2.17	107.57	14.6	+0.020	39
	" 32	15.4	33	-10.75	412.33	16.0	-0.027	68
	" 16	15.2	19	- 1.44	118.69	15.4	-0.013	40
	" 17	15.3	30	-10.29	356.32	16.2	-0.029	63
	" 21	14.9	16	+ 2.12	87.46	14.5	+0.025	33
	" 10	15.9	37	- 5.91	480.28	16.3	-0.012	75
	" 2	17.0	33	+ 7.94	435.79	16.4	+0.018	77
	" 33	16.5	33	+ 0.56	434.00	16.5	+0.001	65
	" 12	15.2	19	- 3.12	94.32	15.8	-0.003	37
	" 6	15.9	27	- 7.21	274.21	16.6	-0.026	52
	" 37	16.2	26	- 5.41	274.67	16.7	-0.019	61
	" 19	15.6	18	- 0.30	129.69	15.6	-0.002	40
	" 31	16.7	39	- 0.44	448.50	16.7	-0.001	75
	" 13	16.6	28	- 2.98	335.83	16.8	-0.008	63
	" 22	16.8	27	+ 0.23	259.05	16.8	+0.001	53
	" 3	14.9	19	+ 0.05	101.83	14.9	+0.001	35
	" 24	16.7	26	-13.33	277.80	16.9	-0.048	55
	" 15	16.7	26	+ 2.79	271.55	16.9	+0.009	54
	" 38	14.9	19	+ 1.64	142.33	15.1	+0.001	42
	" 30	17.3	35	+ 4.32	435.13	16.9	+0.010	72
	" 32	15.9	38	-18.22	610.59	17.0	-0.029	83
	" 16	16.1	29	- 7.90	246.40	17.0	-0.032	57
	" 21	15.1	19	- 0.34	123.00	15.2	-0.003	40

TABLE 53—Continued

	Pedigree	[<i>o</i>]	[<i>t</i>]	[<i>of</i>]	[<i>t</i> ²]	<i>a</i>	<i>b</i>	<i>t</i>
Race 3	" 20	16.8	34	— 2.74	446.79	17.0	—0.006	72
		16.9	37	+ 1.27	482.38	17.0	+0.003	73
	" 3	15.3	18	+ 1.16	124.00	15.1	+0.010	42
		16.8	31	— 3.27	363.86	17.1	—0.009	62
	" 7	15.4	19	— 1.74	133.40	15.6	—0.013	40
		16.6	33	— 8.75	405.17	17.3	—0.022	61
	" 11	15.3	19	+ 2.27	128.28	15.9	—0.019	40
	" 5	16.8	26	— 5.37	277.80	17.3	—0.019	54
		17.2	36	— 1.99	459.27	17.3	—0.004	70
	" 14	15.8	19	— 4.67	73.89	15.9	—0.006	33
	" 27	17.5	34	+ 0.54	409.71	17.4	+0.002	71
	" 4	17.1	37	— 3.57	531.48	17.4	—0.007	76
		16.9	34	— 6.12	410.44	17.4	—0.015	68
	" 1	15.7	19	+ 1.92	134.24	16.0	+0.014	41
		16.7	27	— 6.95	261.05	17.4	—0.026	55
	" 34	15.4	19	+ 0.08	127.83	15.4	—0.001	40
	" 13	17.0	35	— 9.91	548.54	17.6	—0.018	74
	" 23	16.9	35	—10.58	437.52	17.7	—0.024	69
	" 26	17.2	37	— 4.98	471.08	17.8	—0.015	74
	" 29	17.0	39	—12.02	539.00	17.9	—0.022	79
	" 8	17.7	36	— 7.48	463.08	18.3	—0.016	72

mature plants of the F_4 series ranged from 24 to 36 inches in height. This series of plants are shown in PLATES 10 and 11, field no. 53. The habit of growth differs from that of the first growth of race 3 in being less abundantly branched; although maturing early there was no tendency to the development of a new and second period of growth except in one plant.

The values for twenty-nine plants of this race are given in TABLE 54. Values of *a* range from 15.2 to 18.2 and average 16.8 with a standard deviation of ± 0.82 .

The pedigree of this race is almost identical with that of race 3. The immediate parents are two sister plants which differed only slightly in value of *a*.

The rather uniform values obtained are in harmony with the uniformity in habit of growth and general vigor seen in this series. The low values which characterize the series are quite identical with those of the immediate parent and constitute an excellent illustration of the general results that the offspring of parents with low flower values also tend to give low values.

E. Characteristics and history of a semi-dwarf bushy race (race 5). This race is decidedly different from any other that has been isolated thus far. The rather small stature and very

bushy habit of growth are well shown in PLATE 10, which is from a photograph of a row of sister plants of the F_3 generation. The numerous branches are slender and tough. The mature height of these plants in the first year of growth ranged from 26 to 32 inches and in the second year (12 plants living) none exceeded 36 inches in height.

TABLE 54

STATISTICAL CONSTANTS FOR ONE GENERATION (F_4) COMPRISING TWO SERIES OF A SEMI-ROBUST, BRITTLE-STEMMED RACE (RACE 4). CONSTANTS FOR IMMEDIATE ANCESTRY GIVEN IN TABLE 53

Pedigree	[σ]	[t]	[σt]	[t^2]	a	b	t
F_4 . ($A \times E_{22}$)-9-5-1-							
no. 1	15.2	34	- 4.47	390.52	15.8	-0.011	66
" 3	15.5	33	- 5.27	371.17	15.8	-0.014	64
" 2	15.6	39	-11.31	488.31	16.5	-0.023	72
" 4	15.4	36	-13.02	431.28	16.6	-0.034	70
F_4 . ($A \times E_{22}$)-9-5-6-							
no. 1	14.5	14	- 5.28	106.17	15.2	-0.051	37
23	15.7	23	- 5.66	198.82	15.4	-0.029	47
" 2	14.9	30	- 8.19	371.41	15.6	-0.022	63
" 3	15.0	20	- 6.45	167.33	15.8	-0.039	41
" 25	14.9	20	- 8.48	153.29	16.0	-0.055	40
" 6	15.2	24	- 8.21	230.94	16.0	-0.035	49
" 29	14.9	32	-14.88	371.17	16.1	-0.039	64
" 12	15.2	29	-11.30	305.15	16.2	-0.033	58
" 31	15.2	24	-10.78	216.41	16.4	-0.052	49
" 22	15.6	32	-10.57	408.91	16.4	-0.025	67
" 16	15.4	26	-10.56	243.67	16.5	-0.043	51
" 8	15.1	28	-13.56	261.74	16.5	-0.051	55
" 19	15.7	27	-10.49	287.75	16.7	-0.037	57
" 21	15.8	24	- 9.72	236.94	16.8	-0.041	49
" 9	15.5	33	-16.61	411.96	16.8	-0.039	68
" 17	15.9	27	-10.76	271.68	17.0	-0.039	55
" 24	15.1	39	-24.19	481.92	17.1	-0.050	69
" 27	15.9	35	-13.59	398.92	17.1	-0.034	65
" 26	15.8	29	-17.74	408.77	17.1	-0.044	69
" 11	15.5	33	-21.12	403.22	17.2	-0.052	65
" 4	15.8	28	-23.06	439.67	17.3	-0.052	68
" 13	16.3	27	-11.87	289.10	17.4	-0.040	57
" 5	15.6	26	-19.69	271.95	17.5	-0.073	55
" 28	16.3	39	-13.15	440.88	17.5	-0.030	70
" 20	16.0	37	-16.31	386.27	17.6	-0.042	61
" 10	15.9	36	-25.88	495.46	17.8	-0.052	72
" 7	16.4	26	-15.93	157.50	18.1	-0.065	51
" 15	16.8	27	-15.23	287.75	18.2	-0.053	56
" 18	16.8	21	-11.81	181.31	18.2	-0.065	43

Full data for the performance of the series ($E_{22} \times A$)-10-13- are given in TABLE 55. The values of a range from 17.1 to 19.1 with an average of 17.9 with a standard deviation of ± 0.59 . For all plants the rate of change was a minus value. The rather

limited individual variability is quite in accord with the very marked uniformity of vegetative habit. It may be noted that the immediate seed parent of the F_3 series gave a value of a at 17.7, which was slightly above the average of the series to which it belonged. In fact the F_2 series ($E_{22} \times A$) - 10 - showed a tendency to low values, the range dropping to 15.3 (see TABLE 48). The values of the F_3 therefore average somewhat higher and there is less variability among individuals.

Three plants of this F_3 series were selected as seed parents for the F_4 generation. The plants of all three series were quite uniform in the vegetative habit of the race, as will be seen in PLATE 10, to the left, to the foreground, and to the right of field no. 49. The series to the right, however, was late in maturing and the photograph does not show the mature branching.

The three F_4 series of this race were derived from sister plants differing imperceptibly in vegetative habit. In regard to the values of a , however, one parent (no. 13) gave the lowest value (17.1) of the F_3 ; the other two exhibited values slightly above the average.

The F_4 offspring of the parent selected for lowest value among the F_3 of this line gave a range for values of a of 15.1 to 17.7 with an average of 16.4 and a standard deviation of ± 0.66 . The mode has shifted to lower values than were seen in any generation of ancestry. The range, however, was not extended to values lower than some realized in the F_2 (TABLE 48).

The characteristics of the other two series were quite identical. The range of one is from 16.6 to 19.3, the average 17.8, and standard deviation ± 0.56 , while values for the other range from 16.5 to 18.4, with an average 17.3 and standard deviation ± 0.51 . These values agree quite closely with the average values seen in the F_3 from which the series descended. The immediate parents were only slightly higher.

The results here obtained demonstrate that pedigreed line breeding from different parents of a race which itself appears very uniform in the F_3 may isolate strains that are slightly different in performance, the selection for lowest value especially giving a strain in which the range is decidedly shifted.

F. Characteristics and history of a tall-growing race (race 6). This race was isolated or segregated in the F_3 generation. In

TABLE 55

STATISTICAL CONSTANTS FOR TWO GENERATIONS (F_3 AND F_4) COMPRISING FOUR SERIES OF A SEMI-DWARF, BUSHY RACE (RACE 5) WITH THOSE FOR LINE OF IMMEDIATE PARENTAGE. VALUES OF a AND b FOR ANCESTRY GIVEN IN TABLES 48 AND 49

Pedigree	$[\phi]$	$[\psi]$	$[\phi\psi]$	$[\psi^2]$	a	b	t
$F_1. (E_{22} \times A)-10-2$ yrs. old	17.9	41	-22.86	542.12	19.7	-0.043	77
$F_2. (E_{22} \times A)-10-$ no. 13	17.0	22	-5.34	166.76	17.7	-0.034	44
$F_3. (E_{22} \times A)-10-13-$ no. 13	15.9	40	-21.75	713.88	17.1	-0.030	97
" 4	16.0	56	-27.41	1181.71	17.3	-0.023	119
" 1	16.1	54	-23.74	1060.71	17.3	-0.023	110
" 11	15.9	37	-23.07	544.28	17.4	-0.041	78
" 7	16.7	27	-10.03	328.61	17.5	-0.031	63
" 8	16.1	45	-22.62	759.41	17.5	-0.030	92
" 10	16.2	47	-27.06	933.57	17.6	-0.029	98
" 3	16.7	56	-23.24	1116.00	17.8	-0.020	115
" 9	16.2	51	-28.54	929.18	17.8	-0.031	105
" 12	16.6	43	-25.02	725.58	18.1	-0.034	89
" 16	16.8	44	-23.83	750.45	18.2	-0.032	90
" 5	17.4	34	-13.49	493.52	18.3	-0.027	78
" 6	17.1	45	-23.72	693.63	18.5	-0.035	98
" 17	16.1	54	-50.70	1160.97	18.5	-0.044	113
" 2	16.7	47	-37.10	795.68	18.8	-0.046	97
" 15	17.4	48	-33.52	950.12	19.1	-0.035	101
$F_4. (E_{22} \times A)-10-13-12-$ no. 20	17.0	25	+4.23	239.37	16.6	+0.017	51
" 19	17.0	28	+1.46	299.62	16.9	+0.005	56
" 25	16.7	30	-3.86	397.13	17.0	-0.009	68
" 10	16.9	30	-0.24	380.76	17.0	-0.002	61
" 15	16.9	27	-3.12	282.00	17.2	-0.011	54
" 23	16.7	21	-7.24	240.65	17.3	-0.029	49
" 13	17.3	27	-0.59	299.29	17.4	-0.002	56
" 8	17.0	21	-2.91	172.69	17.4	-0.017	43
" 12	17.2	22	-5.77	477.78	17.5	-0.012	65
" 18	16.7	36	-13.29	521.08	17.6	-0.026	73
" 17	18.0	16	+2.40	106.75	17.6	+0.023	35
" 2	16.8	32	-11.83	366.66	17.8	-0.032	64
" 6	16.8	30	-10.81	333.69	17.8	-0.033	63
" 14	17.1	31	-9.51	355.05	17.9	-0.026	63
" 5	17.4	30	-6.61	338.73	18.0	-0.019	62
" 3	17.4	27	-5.93	279.30	18.0	-0.021	57
" 1	16.9	26	-11.89	284.55	18.0	-0.042	56
" 16	17.3	24	-7.43	217.67	18.1	-0.034	49
" 7	16.8	24	-14.34	247.11	18.2	-0.058	51
" 11	16.8	22	-12.65	187.75	18.3	-0.067	44
" 22	17.6	23	-9.04	215.06	18.6	-0.042	48
" 4	17.8	21	-8.55	162.27	19.0	-0.052	41
" 21	16.8	27	-9.73	107.60	19.3	-0.091	55
$F_4. (E_{22} \times A)-10-13-13-$ no. 12	15.2	34	+1.31	438.25	15.1	+0.003	69
" 36	15.4	32	-1.69	398.61	15.5	-0.004	64
" 27	15.4	35	-2.39	433.63	15.6	-0.005	69
" 15	15.7	24	+0.97	264.00	15.6	+0.003	50
" 26	15.6	35	-1.62	441.13	15.7	-0.004	70
" 33	16.5	24	+5.72	234.06	15.9	+0.025	50

TABLE 55—Continued

Pedigree	[<i>o</i>]	[<i>t</i>]	[<i>ot</i>]	[<i>t</i> ²]	<i>a</i>	<i>b</i>	<i>t</i>
" 5	15.3	32	— 7.99	361.00	16.0	—0.023	62
" 2	15.6	32	— 6.20	360.50	16.1	—0.014	61
" 9	15.5	29	— 6.93	334.20	16.1	—0.020	64
" 22	15.7	32	— 5.87	428.95	16.1	—0.014	68
" 30	15.0	35	—16.60	559.60	16.1	—0.029	76
" 34	16.6	34	+ 5.46	389.39	16.1	+0.014	66
" 11	15.6 _a	31	— 7.76	336.38	16.3	—0.023	64
" 19	16.0	30	— 6.04	343.53	16.5	—0.018	61
" 35	15.5	34	—12.68	447.67	16.5	—0.028	67
" 17	15.9	30	— 7.95	400.73	16.5	—0.020	67
" 16	16.1	27	— 6.29	278.00	16.7	—0.023	71
" 21	15.5	33	—15.52	418.43	16.7	—0.037	70
" 28	15.7	40	—16.28	603.04	16.8	—0.027	82
" 18	16.1	33	—12.15	548.20	16.8	—0.022	71
" 7	15.8	31	—12.92	406.85	16.8	—0.032	65
" 8	15.6	33	—16.75	421.09	16.9	—0.039	68
" 4	15.9	37	—16.40	502.00	17.1	—0.033	77
" 20	16.2	31	— 9.58	334.57	17.1	—0.029	62
" 24	16.5	23	— 6.62	217.29	17.2	—0.029	48
" 6	15.8	30	—20.22	411.55	17.3	—0.049	71
" 1	15.5	39	—25.06	555.44	17.3	—0.045	76
" 32	16.4	33	—16.25	420.00	17.7	—0.039	67
F ₄ . (<i>E</i> ₂₂ × <i>A</i>)—10-13-5-							
no. 41	16.9	23	+ 3.97	211.29	16.5	+0.019	48
" 23	16.5	31	— 0.38	347.09	16.6	—0.002	60
" 16	16.6	27	+ 0.59	310.86	16.6	+0.001	56
" 30	16.5	28	— 2.85	286.90	16.8	—0.010	54
" 5	16.5	24	— 4.22	228.67	16.9	—0.018	50
" 25	16.6	27	— 3.33	258.21	17.0	—0.013	58
" 24	17.0	25	— 0.79	263.21	17.1	—0.005	53
" 39	16.4	26	— 8.03	285.70	17.1	—0.028	54
" 1	17.4	27	+ 2.54	317.73	17.2	+0.007	58
" 27	16.3	25	— 9.66	306.74	17.2	—0.036	56
" 6	17.0	28	— 4.24	311.48	17.4	—0.014	55
" 13	17.0	30	— 5.95	321.76	17.5	—0.017	62
" 12	17.2	25	— 3.81	326.67	17.5	—0.012	58
" 11	17.6	31	+ 5.07	348.04	17.5	+0.015	64
" 8	16.8	31	— 5.75	272.32	17.5	—0.021	60
" 37	17.3	31	— 3.26	371.17	17.6	—0.009	54
" 22	17.0	21	— 6.38	188.35	17.7	—0.034	43
" 33	17.2	28	—11.20	336.28	18.2	—0.034	58
" 31	17.3	25	—11.54	266.21	18.4	—0.043	54

this race there is a vigorous development of the main axis, which reaches a height of from 3 3/4 to 5 feet in the first year of growth with rather weak development of lateral branches; laterals from near the base of the main axis are wanting and there is feeble development of secondary laterals from such laterals as develop. The main axis is very leafy with leaves of robust growth and of gradual transition to rosette leaves. When mature the plants of this race appear as shown in PLATE 10 (field label 49). Through-

out their growth they are decidedly in contrast to the other races already described.

TABLE 56

STATISTICAL CONSTANTS FOR TWO GENERATIONS (F_3 AND F_4) COMPRISING THREE SERIES OF A TALL-GROWING RACE (RACE 6), WITH THE VALUES FOR THE F_2 PARENT

Pedigree	[ϕ]	[l]	[ϕl]	[l^2]	a	b	t
F_2 . ($E_{22} \times A$)-10- no. 8	17.1	40*	- 6.56	344.28	17.7	-0.019	67
F_3 . ($E_{22} \times A$)-10-8- no. 4	16.8	38	- 9.40	535.58	17.4	-0.017	76
" 13	17.3	39	- 5.46	561.36	17.7	-0.011	78
" 15	16.4	44	-23.31	758.37	17.8	-0.032	91
" 14	16.6	35	-18.56	491.63	17.9	-0.038	75
" 12	16.3	34	-25.00	518.30	18.0	-0.049	78
" 8	17.1	18	- 7.06	129.31	18.1	-0.053	37
" 3	17.4	31	-13.78	518.83	18.1	-0.027	74
" 6	17.1	21	- 7.12	124.47	18.3	-0.057	52
" 7	17.5	28	-13.67	365.16	18.5	-0.037	72
" 11	17.8	25	- 9.66	226.33	18.9	-0.043	50
" 1	18.2	39	-17.17	619.32	19.3	-0.028	83
" 5	18.5	28	-11.72	320.26	19.5	-0.036	60
F_4 . ($E_{22} \times A$)-10-8-15- no. 11	15.8	30	-16.47	317.63	17.4	-0.052	62
" 4	17.0	27	- 6.70	301.75	17.6	-0.022	61
" 1	17.0	34	-11.75	440.32	17.9	-0.027	59
" 16	17.1	34	-10.54	391.55	18.0	-0.026	61
" 5	17.6	21	- 4.31	199.53	18.1	-0.022	48
" 2	18.1	16	- 9.28	989.33	18.2	-0.009	32
" 17	17.1	21	-12.81	215.50	18.3	-0.059	51
" 14	17.0	28	-14.70	297.15	18.4	-0.049	56
" 8	17.1	24	-15.67	238.72	18.7	-0.066	49
" 6	17.4	29	-16.02	333.09	18.8	-0.047	61
" 15	17.0	24	-18.45	217.24	19.0	-0.085	47
" 9	17.1	33	-24.90	416.33	19.1	-0.060	67
" 12	17.1	24	-16.15	177.72	19.3	-0.091	49
" 7	17.7	33	-24.10	414.04	19.6	-0.059	52
F_4 . ($E_{22} \times A$)-10-8-14- no. 9	15.7	29	- 2.35	310.05	15.9	-0.008	58
" 1	15.7	31	- 4.38	372.48	16.1	-0.012	63
" 18	15.7	34	-12.66	394.87	16.8	-0.032	68
" 5	16.2	29	- 8.95	256.57	17.2	-0.034	57
" 6	15.4	36	-23.36	482.00	17.2	-0.049	73
" 8	16.5	30	- 8.69	322.41	17.3	-0.027	58
" 16	16.9	31	- 4.24	433.37	17.3	-0.010	70
" 2	17.1	27	- 5.24	278.50	17.6	-0.020	54
" 7	15.6	33	-24.39	399.46	17.6	-0.062	66
" 10	16.0	32	-22.83	397.21	17.8	-0.057	67
" 3	16.9	33	-10.53	382.29	17.8	-0.026	65
" 12	15.9	32	-25.17	381.58	18.0	-0.065	64
" 11	16.4	27	-25.97	391.91	18.2	-0.067	63
" 15	17.4	29	-10.39	310.05	18.4	-0.033	58
" 4	17.3	29	-13.95	307.71	18.6	-0.046	60
" 13	17.7	30	-26.93	349.57	19.9	-0.073	61

For the F_3 series of twelve plants (TABLE 56) values of a ranged from 17.4 to 19.5 and averaged 18.3 with a standard deviation of

± 0.62 . The further performance of this race was observed in two series of F_4 , the progeny of two plants, with values of a which were somewhat lower than the average of the series. In regard to the actual range for values of a and averages, one series was decidedly higher, more uniform and less variable; its progeny digressed toward the higher average of the generation to which the parent belonged. For the other series ($-10-8-14-$), the average a was somewhat lower than the value of the immediate parent, and the range was extended to lower values than were seen in the parent series. All plants of the F_3 and F_4 of this race gave minus values for rate of change.

The two radically different races, semi-dwarf bush (race 5) and the tall-growing race (Race 6), descended from the same F_1 parent ($E_{22} \times A$) no. 10.

The six races noted above all descended from three sister F_1 plants which were quite alike in general vegetative characters. The three main lines of descent split up into six rather widely differing races. In regard to values of a , it may be noted (TABLE 48) that races that segregated from the same line were of the same general performance. Values for races 1 and 2 were relatively high, those for races 3 and 4 were relatively low and those of 5 and 6 were more intermediate.

The differences in values for the lines and the noticeable uniformity within races, especially in the F_4 , is proof that somewhat slight differences in number per head are hereditary. Although self-sterility of many plants prevented a rigid testing of the effects of selection, there is decided evidence, as noted above, that selection for high or low values within a race is in some degree effective.

A further point appears to be clear. The very marked vegetative differences may affect very strongly the total number of heads produced, but such vegetative differences are only slightly concerned with changes in the performance as measured by such values as o and a .

DISCUSSION AND CONCLUSION

The aim of the earlier investigators who made statistical studies of number of flowers per head was to obtain exact descriptions of species as such. By determining the number that is characteristic of various species, the degree of specific differentiation in respect to the character of flower number would appear. The results of the various statistical studies (of Ludwig especially) of flower number, although chiefly directed to ray-flowers, have been considered as indicative of specific differentiation, as noted in the review of literature. That the number of rays is not closely or rigidly stable is very evident, however. A rather wide range of variability is nearly always in evidence, and this has led investigators to judge a species by some such value as the average or modal number. When thus judged, it seems clear that species differ and that a species may tend to maintain a particular maximum. The studies with chicory, viewed from this standpoint, indicate that the total number of flowers per head may range in this species from 5 to 34 and that the number per head most frequently produced is somewhere from 17 to 19.

The view held by Ludwig maintains that the numbers for ray-flowers characteristic for species as such conform to such a series as that of Fibonacci, hence there is proof of discontinuous variation or mutation in the evolution of species. However, the data are not fully in accord with this view. It appears that there are some maxima that fall on certain primary numbers of the Fibonacci series and such cases do suggest that fundamental rhythmic processes of development may have occurred giving specific series of numbers for such organs as rays in flower heads. That all flower-number differences seen among and within species thus arose is not indicated, for there are evidently numerous cases of maxima that do not fall on either primary or well-recognized secondary numbers of such series. It will readily be recognized that the indiscriminate statistical study in populations of such a variable character as number of flowers per head centers the attention on general or average performance and fails to recognize the effects of individual and partial variability of a character. Furthermore, a study of individual and partial variabilities

furnishes valuable clues as to whether the origin or evolution of different flower numbers per head is of continuous or discontinuous nature.

When the data for an individual plant of chicory are massed there is most often a rather pronounced mode or maximum. A certain number of flowers per head on a plant occurs with greatest frequency. The modal number, however, is not the same for the various individuals of a mixed population or even of a race: for some individuals it falls on as low a number as 14; for others it falls as high as 22. In relatively few cases do the maxima fall on one of the primary numbers of the Fibonacci series and the grand maximum certainly does not thus fall.

A consideration of variation within the individual (partial variability) shows that the number of flowers per head in chicory may range on a single plant from 7 to 31. The primary numbers 8, 13, and 21 of the Fibonacci series are thus all represented on a single plant and the range extends almost to the next in order, 34. Furthermore, as a rule, all numbers between the extremes are represented on an individual. The variations within the individual are certainly continuous rather than discontinuous, at least to the extent that there is no rhythmic discontinuity with jumps to one after another of a series of maxima.

The questions of chance variation, differentiation, and symmetry deserve special mention. In chicory, it is clear that the differences in number per head are not purely chance variations that are due to undiscoverable factors. As fully noted in the literature review above, nearly all the statistical studies, both in methods of collection and in treatment of data, have considered the variations in flower number to be purely chance; but the results obtained in chicory suggest that there may be present sources of variation that are due to differentiation in the sense used by Pearson. The data here reported show that position is a factor influencing flower number. As terminals bloom before their immediate laterals, differences according to position appear in the course of the succession of bloom, giving intraseasonal partial variability. In this sense the more lateral and later-blooming heads are differentiated from the more terminal and earlier-blooming heads of the same plant.

However, the distinction between chance variation and discoverable differences according to position (differentiation) in such similar organs as flower heads in chicory is by no means clear. Partial, chance, or fluctuating variations are of such intergrading ranges that differentiation according to position would not be discovered by such indiscriminate and chance methods of study as have usually been employed. Considering the first terminals and the last laterals which bloom on a plant, there is, as a rule, a very marked difference. There is also a difference between terminals of various ranks. But for certain terminals the number of flowers per head is identical with that of certain laterals; one class grades into the other. A strict interpretation of differentiation, however, would perhaps lead one to the view that even the variation seen in any one day among closely homologous terminals or laterals produced on a plant is significant of still finer grades of differentiation.

Such a view would evidently recognize a symmetry of development giving primary, secondary, and tertiary branches. If such be the case, it is clear that the transition from one to the other is more continuous than discontinuous; at least the gradations are slight. Although differentiation is in evidence, and is readily discoverable, it is not obviously discontinuous.

In chicory the repeated branching and deliquescent habit of growth with terminal and lateral branches of various ranks and series give opportunity for a full expression and development of marked differentiation of the sort discussed above. If the differentiation which does occur in chicory in development of number of flowers in such homologous organs as flower heads is any measure of differentiation between individuals, races, or species as such, it is indicative of continuity rather than discontinuity.

In judging an individual as a whole for flower number per head, the collection of data at the beginning of the blooming season will give a different estimate from what would be obtained at the close of the blooming season. As a rule, higher values prevail in the first part of the blooming period. The variability observed will be less the shorter the period of time covered. There will be less variability with the limitation of data to terminals only, to laterals only, or to terminals or laterals opening during one day.

The collection of data from a number of individuals to be compared in any sort of statistical study may therefore involve several decided elements of error. The collection of the same amount of data is not alone adequate, for the two sets may represent different relative periods of bloom. Even if data were taken for a period of bloom, as for the first ten days, they would most often represent different proportions of the entire period of bloom. Data from the last period of bloom only would give an unreal and apparent similarity between plants, as all plants are more nearly alike in the lower numbers per head produced during the late season. Data for the first period of bloom would emphasize the differences in the higher numbers per head. Indiscriminate collection of data from individual plants therefore involves so many sources of misrepresentation as to be of little use in formulating any conclusions. It is quite possible that much the same condition exists in respect to the hereditary studies of such characters as the size of flowers (as Goodspeed and Clausen, '15, have suggested) or as the size and weight of fruit produced or of any other character which is subject to such degrees of partial variability.

The data for chicory indicate that there is much individual variability in such a character as number of flowers per head. Such differences as total number of flower heads and length of blooming period are quite closely correlated with vegetative vigor and variations of this sort are seen even in closely inbred and very uniform races. Much more fundamental differences exist especially between plants of different races or between races as such. The modal number and the computed value of the first day of bloom may be quite different. The rate of change as determined by values of b may be decidedly different, even to the point of exhibiting no seasonal decrease or even of revealing an actual increase in number as the season advances. While such cases are not numerous they are sufficiently frequent (for this the data are fully convincing) to indicate that the usual processes of noticeable differentiation according to position which result in seasonal decrease may not be in evidence or may even be reversed in their operation so that the differences between terminals and laterals as to number per head do not appear and hence both terminals and laterals show much the same range of variation. These

individual differences arise among plants of the same age that have been grown under as similar conditions as is possible under greenhouse and garden culture.

The individual variations observed are to be considered as fluctuating and continuous. They indicate that the character of flower number is constantly varying, giving differences upon which selection may operate in the isolation of races.

The performance of races with marked differences in vegetative habit of growth gives some clue to the extent to which the character of flower number per head can be modified in correlation with different habits of growth. The various races range in habit from extremely robust and much branched races with annual production of large numbers of flower heads to small dwarf races which produce only a few flower heads in a season. The total number of heads produced and the length of the blooming period are greatly modified in such cases. The character of number per head, however, remains more constant. In the most vigorous types we have found, as a rule, high values for the computed number of first day of bloom. Also, it is in the most vigorous races that partial variability is greatest in degree, for here lowest numbers per head (as low as 5) are found.

The possibility of isolating races which will exhibit characteristic differences (although often slight) in flower number is well demonstrated, though rigid selection is here difficult because of the limitations imposed by self-incompatible plants. The continued selection in self-fertilized lines of descent for extreme and unusual characteristics appearing within a race is impossible in chicory because of self-sterility and the limits of the effects of selection cannot be so rigorously tested as is possible in a species fully self-compatible.

Hereditary variations of slight differences and of continuous gradation appear in every group of organisms with which extended studies of heredity have been made. The two current interpretations of such phenomena are (1) those of the strict adherents of the genotype theory who see only recombinations of Mendelian units and (2) those of the selectionists who see evidence of continuous alterations in constitution upon which selection may operate.

The experiments of Castle and Phillips ('14) show that selection for variations in color patterns of rats led to a gradual increase or decrease in the amount of pigmentation, ultimately giving quite diverse patterns. These results have been continuously and consistently interpreted by Castle to indicate that "genetic factors are themselves variable" and that such factors may be altered gradually but permanently by repeated selection and "that one must reject the conception of modifying factors and conclude that the character has a high degree of genetic stability yet is subject to continuous genetic fluctuation" (Castle and Phillips, '14; Castle, '16a, '16b, '17, and other papers).

Much the same sort of variability has been demonstrated, however, in progenies propagated asexually by Stout ('15) in *Coleus* and Jennings ('16) in *Diffugia*. Here the fundamental hereditary characters are shown to be subject to slight and hereditary alterations.

Jennings ('17) points out that modifying factors, postulated by the opponents of the doctrine of fluctuating change in hereditary constitution to account for a series of graded variations in sexually reproduced and cross-bred organisms, are themselves alterations.

Johannsen ('03) claims that in respect to such a variable character as weight and size of seeds an ordinary population of beans consists of a number of genotypes (races) which can be discovered by growing and comparing the progeny of single seeds. Each progeny constituting what he calls a pure line was considered as breeding true except for occasional mutations. Johannsen thus sought to apply the doctrines of discontinuous mutation then so recently announced by de Vries and to establish the genotype theory to account for the isolation of races differing in hereditary constitution (genotype). The variations appearing within a line of progeny were considered as purely due to environment (phenotypic).

There are at least two methods of attacking the problem as to the inheritance of variations, such as those of weight of seeds within a line of progeny:

1. By comparing the seed weights of progeny of small and large beans irrespective of immediate parentage within the line and irrespective of a consideration of individual or partial variability.

2. By comparing the progeny of different plants which vary in the average of their total product, with the estimate of individual variabilities which takes into account the partial variabilities that are present.

Either method is good if properly carried out. The first method, however, is less satisfactory in that it does not consider partial variability. The extremes of partial variations may include, as they do in chicory, the very lowest and the highest values of range. It is, however, the first-named method that Johannsen chose to use. Furthermore, the far-reaching conclusions published by Johannsen ('03) were based on the results of *one crop for which the offspring of small and large seeds produced by the same plant were grown and compared as to size and weight of seeds which they produced as classes*. As far as any line was concerned, the selection constituted a test for the heredity of *partial variations only*, as Belling ('12) has already noted. The negative results obtained indicate that the weight of individual seeds produced in the same pod or in different pods on the same plant, as was the case in each of the 19 lines, is largely due to differences in nutrition (phenotypic), resulting from position in the pod or to relative position of the pod. It seems clear that adequate tests for the heredity of variations in the character of weight of seeds in beans should be based on the performance of plants as wholes rather than on the weight of the individual seeds.

Johannsen ('13) reports progenies beyond his first generation from a known parent plant (his 1902 crop) from only two of the original nineteen plants. These two were plants of near the average rather than the extreme performance. In these two lines of progenies, however, the performance of individual plants was not considered and as selection was on the basis of the weight of individual seeds, those selected for high and low weights may have repeatedly had the same parentage.

Even with this method, however, there is evidence that hereditary variations of fluctuating nature arose within a line. In line I, the weight range of beans produced by the parent plant (1901) extended from 550 to 750 milligrams. The next crop of seeds (produced by at least several sister plants) ranged from 350 to 900. For several years later the *average weights* of the heavier

and the lighter seeds planted were beyond the limits of the entire range of the seeds of the original parent plant. The actual ranges of the successive crops, which might show multimodal irregularity, are not given; only the average weights of all above or below the mean are presented. Here, however, the data show that the range of variability in offspring of a single plant may far exceed that of an original parent. While this increased variability is interpreted by Johannsen as within the range of variability of the genotype such results are not at all inconsistent with the view that actual changes in hereditary constitution are in evidence which when subjected to such careful selection as that employed by Castle and Phillips may result in the isolation of further genotypes within the "pure line."

The necessity of considering the performance of individuals as units in judging a progeny, or a line of progenies, and of representing on this basis the individual variations rather than the partial variations occurring within the individual, when such fluctuating characters as weight of bean seeds and number of flowers per head in composites are involved, is well shown in the studies of chicory reported above. The greatest difference between individuals and between races as such (in respect to flower number) is seen in the production of higher numbers per head rather than of lower numbers. The tendency of the variabilities is to extend the range of flowers per head to higher numbers keeping the range in lower numbers much the same. There is not a decided shifting of the entire range to higher and lower values for the plant or the race as a whole.

This characteristic variability among races, to extend or to limit the range in high numbers rather than to shift the entire range, indicates that racial differentiation is here quite different from that which appears to have prevailed in the races which de Vries ('01) isolated in *Chrysanthemum segetum*. However, de Vries confined his attention chiefly to terminal flowers and practiced a rigid selection for extremes only. In isolating the race with 21 rays per terminal head, various intermediates ranging as low as 13 for a maximum were discarded. At any rate, the isolation of two extreme races by de Vries is no proof that other and intermediate races could not also be isolated quite as they have been in chicory.

The differences between varieties or races of chicory are, considered as a whole, quite continuous. The average number of flowers per head for the first date of bloom (a) (computed from the seasonal record of the various members) for the different races isolated in F_3 and F_4 ranges from 20.4 to 16.7. These averages, however, are from distributions that are overlapping (TABLE 48). If the races having highest and lowest values of a be massed in population, the curve will be bimodal, the irregularity of which depends largely on the relative numbers. If the race with intermediate values be also massed, then the curve becomes monomodal.

It is clear that in chicory flower number per head is a character that is subject to wide and continuous variability that is (1) partial (existing among the parts of a single individual and here involving also elements of differentiation according to position), (2) individual (characteristics of plants as wholes based on their entire record), and (3) racial (fluctuating about a mode that can be somewhat closely maintained by selection). The differentiation between races as such, however, is no more marked than the differentiation involving position that occurs among the various parts of the individual. Most especially is the character of number of flowers per head subject to modification during ontogenetic development and epigenetic processes of growth. *Flower number per head is very different, therefore, in nature from the general character of the inflorescence as a whole and from the character of flowers as individuals.* All flowers are quite alike, all are in heads, but the number of similar flowers that are thus grouped is variable.

The operation of heredity in such a character as flower number is seen in the isolation of races which may be maintained by such selection as was possible in chicory. Within each race, however, there are further variations, continuous in gradation and of the same nature as those appearing in a more mixed population, which are unmistakable evidences of the instability of characters and hereditary units.

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EXPLANATION OF PLATES 10-13

PLATE 10

Field view of chicory crop of 1916. Field label 49 designates a series of the tall-growing race [race 6, series $(E_{22} \times A)-10-8-15-$]. Plants of the semi-dwarf bushy race (race 5) are shown at the right [series $(E_{22} \times A)-10-13-5-$,] in front [series $(E_{22} \times A)-10-13-13-$], and at left [series $(E_{22} \times A)-10-13-12-$] of field label 49. Field label 53 marks a series $(A \times E_{22})-9-5-6-$, of the brittle-stemmed race (race 4).

PLATE 11

View in field of chicory, crop of 1916. To left, field label 53 marks a series of the brittle-stemmed race shown also in plate 10. Next to the right are plants of the semi-dwarf race [race 1, series $(A \times E_{22})-4-3-11-$]. In front of label 63 are plants of the dwarf race [race 2, series $(A \times E_{22})-4-6-3-$]. Field label 63 designates plants of series $(A \times E_{22})-9-5-6-$ and label 57 marks series $(A \times E_{22})-9-4-10-$, both of which constitute distinct races thus far unnamed.

PLATE 12

Branches of chicory from near middle part of plants. A is from the wild white-flowered plant A used as a parent of various families; B is from plant E_3 of the variety Barbe de Capucin, and C is from an F_1 hybrid of $E_3 \times A$.

Heads that are solitary and on terminal or elongated stems are indicated by 1. Sessile flower heads lateral to more terminal heads are indicated by 2. Clusters of sessile heads are shown at 3.

As shown, especially in A, the terminal head blooms before a head that is immediately lateral to it. In the flower clusters the first head to bloom is the main terminal.

The three branches illustrate some of the variations that occur in regard to the number of solitary and grouped heads.

PLATE 13

Segments of a single large branch from each of four different plants showing the grouping of heads, the relative development of successive laterals on a branch, and the variation which is seen in different plants (individual variability) in the character of the clusters of flower heads.

A is from a plant of the variety red-leaved Treviso. (*R. ser. 11, no. 14*). At 8 is a terminal segment with a solitary head at apex and at first node. Segments 7 to 4 inclusive show a terminal and a single lateral at each node with various stages of elongation of the stem bearing the terminal. Segments 1, 2, and 3 show further development; the succession of bloom indicated by letters.

B is from a plant of the F_1 generation of the cross between a plant of red-leaved Treviso and the wild white-flowered plant A (plant *RA, ser. 2, no. 5*). Shows rather extreme development of ultimate branches giving few sessile flower heads, a characteristic quite marked in plants of red-leaved Treviso and in wild plants.

C and D are from two plants of the brittle-stemmed race (race 4) showing reduction of the ultimate branches with production of clusters of sessile flower heads. In such clusters are terminals and laterals of different ranks.